BRI International Green Development Coalition
2023 Policy Study Series

BRI Case Study Report on Green Transport

In April 2019, Chinese and international partners officially launched the BRI International Green Development Coalition (BRIGC) at the Second Belt and Road Forums for International Cooperation. BRIGC aims to establish a policy dialogue and communication platform, an environmental knowledge and information platform, and a green technology exchange and transfer platform, so as to advance global consensus, understanding, cooperation, and action of a green Belt and Road Initiative (BRI).

Transport infrastructure connectivity, represented by railways, highways, ports and airports, is viewed as the core and leading field of BRI cooperation. Promoting the green development of transport infrastructure is of great significance to constructing the green Silk Road as well as achieving global biodiversity conservation and climate change targets.

This report, focusing on green transport infrastructure and green commuting, carried out a case study on BRI green transport. With 13 typical cases of different sectors, including railways, highways, ports, bridges, tunnels, and electric vehicles, the report fully demonstrates the best practice of the BRI green transport development, delivers the measures taken and effects made in protecting the local eco-environment, improving people's livelihood, and serving the host country's development strategies.

Since 2019, BRIGC has released a series of case reports, including the BRI Green Development Case Study Report (2019), the BRI Green Development Case Study Report (2020), the BRI Case Study Report on Green Development of Cities, and the BRI Case Studies Report on Biodiversity Conservation, which systematically summarize the practical experience of the BRI green development and provide reference for continuing to promote the high-quality development of BRI.

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Contents

Executive Summary

Since its proposal in 2013, the Belt and Road Initiative (BRI) has always adhered to open, green and clean cooperation, pursuing high standard goals to improve people's livelihood and promote sustainable development. It has become one of the world's most popular public product and platform for international cooperation. As a critical part of BRI construction, cooperation in transport is the foundation of connectivity. Up to January 2023, China has signed more than 200 documents for BRI cooperation with 151 countries and 32 international organizations,[1] most of which were of transport infrastructure and connectivity. By the end of 2021, there are 22 bilateral and multilateral intergovernmental agreements on international road transport facilitation signed between China and other 19 countries based on the platform of BRI cooperation[2].

A sluggish global economic recovery, compounded with multi-dimensional challenges including climate change, biodiversity loss, environmental pollution and unbalanced development, has driven major industries to step up their efforts in carrying out green and low-carbon transformation strategies. Among them, the impact of the transportation sector on the eco-environment and climate .should be reckoned with. On the one hand, there are many long-distance linear traffic projects involved in the BRI construction, which overlap with the eco-environment sensitive areas along the Belt and Road Transport infrastructure is leaving increasingly greater influence on the natural landscape and ecosystem, such as habitat degradation and fragmentation, environmental pollution, habitat barrier and alien species invasion, covering at least 15% to 20% of the global land area [3]. On the other hand, transport is one of the major industries in energy consumption and greenhouse gas emissions. Data of the International Energy Agency (IEA) shows, transportation, as the second largest carbon emission sector in the world, 25% of the total, is the main factor causing global climate change.

China has always regarded green transportation as an important field to promote the construction of the Green Silk Road. In April 2017, the Ministry of Environmental Protection (MEE), the Ministry of Foreign Affairs (MOFA), the National Development and Reform Commission (NDRC) and the Ministry of Commerce (MOFCOM) jointly issued *the Guidance on Promoting the Green Belt and Road*, taking "promoting green infrastructure and prioritize environment quality" and "popularizing energy conservation and environmental protection standards and practices in such sectors as green transportation ..." as one of the main tasks. In October 2021, during the Second United Nations Global Sustainable Transport Conference, China reiterated to the world that it would continue to advance high-quality Belt and Road cooperation, strengthen infrastructure connectivity with other countries, and develop a green Silk Road and a digital Silk Road at a faster pace. In March 2022, the *Opinions on the Joint Implementation of Green Development in the Belt and Road Initiative* was jointly issued by NDRC, MOFA, MEE, and MOFCOM, stressing on "advancing international cooperation in the field of green transport, to help BRI participating countries develop green transport."

This report, focusing on green transport infrastructure and green commuting, carried out a case study on BRI green transport. With 13 typical cases of different sectors, including railways, highways, ports, bridges, tunnels, and electric

vehicles, the report fully demonstrates the best practice of the BRI green transport development. In delivering the measures taken and effects made in protecting the local eco-environment, improving people's livelihood, and serving the host country's development strategies, this study will provide useful reference for the BRI participating countries, contributing to the construction of the green Silk Road to achieve better results.

Chapter I Introduction

Studies on green transport began in the early 1990s. In 1992, the United Nations Conference on Environment and Development (UNCED), adopted the Rio Declaration on Environment and Development (also known as the Earth Charter), in which sustainable development was listed as the common goal of human development for the first time. Under this framework, green transport has been applied in the urban transportation as an important part, transport systems featuring cost-effective, more efficient, less polluting and safer[4]. Chris Bradshaw, Canadian scholar, proposed the Green Transportation Hierarchy in 1994, first linked urban transportation with energy and environment. As a diversified transport system, the Green Transportation Hierarchy is an important means for easing traffic congestion, solving urban pollution, and reducing uses of energy, resources and land, which actively promotes social sustainability. The priority order of green transportation is as walking, bicycle, public transport, shared vehicle, and single-driving vehicle as the last[5].

In the 1990s, China started its research on transport transformation. In 1995, China's Urban Transport Development Strategy: Proceedings of a Symposium in Beijing, jointly sponsored by the former Ministry of Construction (MOC), now the Ministry of Housing and Urban Rural Development, MOHURD), the Ministry of Finance (MOF), the People's Bank of China (PBOC), the World Bank (WB) and the Asian Development Bank (ADB). This document basically laid the foundation for China's priority and vigor in developing public transport and promote green commuting. In 2003, MOC and the Ministry of Public Security (MOPS) of China launched an event of creating "demonstration cities of green transport", formally specifying the connotation of green transport in the *Instructions of Assessment Standards for Demonstration Cities of Green Transport*. "Green Transport refers to the urban transport system that adapts to the development trend of the residential environment. The goal is to build a diversified urban transport system that is eco-friendly, and dominated by public transport, featuring convenience, safety, high efficiency, low pollution and satisfying landscape. Aimed at

promoting the coordinated development of urban transport and construction, improving transport efficiency, protecting the culture and traditions of cities, and cleaning the urban environment, an urban transport environment, compatible with the city's social and economic development, would be created by taking science-based methods, technologies and measures." Following this document, a series of policies concerning green transport were released by the Chinese government, as shown in the Table 1.

Table 1: China's Main Policies for Green Transport

DOCUMENTS	TIME	ISSUERS	CONTENTS
Notice on Launching the Event of Building "Demonstration Cities of Green Transport"	August, 2003	MOC, MOPS	Specifying the connotation of green transport: in promoting and applying new technologies of transport infrastructure design and new methods of transport operation and management, to build up a convenient, fast, safe, efficient, low-pollution, and eco-friendly diversified urban transportation system.
Guiding Opinions on Promoting the Development of Green, Recycling-Oriented and Low-Carbon Transportation	May, 2013	Ministry of Transport (MOT)	Setting a goal of basically completing a green, recycling-oriented and low-carbon transportation system by 2020. Main tasks include: to strengthen the green, recycling-oriented and low-carbon requirements in constructing transportation infrastructure, and to accelerate the application of energy-saving

			and eco-friendly transportation equipment, among others.
Green Transportation Standard System (2016)	December, 2016	MOT	Defining the standards for green transportation, such as energy conservation and carbon reduction, ecological protection, pollution prevention and control, resource recycling, and monitoring, evaluation and supervision.
Guidance on Promoting Green Belt and Road	April, 2017	MEE (former), MOFA, NDRC, MOFCOM	Boosting green infrastructure and prioritize environment quality. To formulate environmental protection standards and codes for infrastructure construction, increase environment protection service and support for major infrastructure construction projects along the route, popularize energy conservation and environmental protection standards and practice in such sectors as green transport, green building and clean energy.
The Belt and Road Ecological and Environmental Cooperation Plan	May, 2017	MEE (former)	Promoting green low-carbon construction, operation and management of infrastructure. To improve green and low-carbon operation, management and maintenance of facilities by

			clarifying environmental protection requirements in infrastructure construction standards and enforcing environmental standards and practices in such sectors as green transportation, green building and green energy.
Opinions on Comprehensively Promoting the Development of Green Transportation	November, 2017	MOT	Carrying forward major green transport development projects in a holistic manner: optimization of transport structure, innovation of transport organization, promotion of green travel, intensive utilization of transport resources, upgrading of efficient and clean transport equipment, prevention and control of transport pollution, and ecological protection of transport infrastructure.
Three-year Action Plan for Winning the Blue Sky War	June, 2018	the State Council	Actively adjusting the transportation structure and developing a green transport system: optimize and adjust the cargo transportation structure, to raise the share of railway cargo transportation, expedite the upgrading of automobile, ship and oil products, and tighten the control of pollution from mobile sources.

Green Travel Action Plan (2019-2022)	May, 2019	MOT and other 12 departments and units	By 2022, to build up a basic service system for green travel, with reasonable layout, eco-friendly, clean and low-carbon, intensive and efficient.
Outline for Building China's Strength in Transport	September, 2019	The CPC Central Committee and the State Council	Promoting green, low-carbon, resource- and energy efficient, low-pollution, and eco-friendly transport systems: (1) promoting resource conservation and intensive use; (2) strengthening energy conservation, emission reduction and pollution prevention, to conduct "green travel" actions and advocate the concept of green and low-carbon travel; and (3) strengthening the restoration of transport eco-environment protection, to build "green transport corridors".
Outline of National Comprehensive Three-dimensional Transportation Network Planning	February, 2021	The CPC Central Committee and the State Council	Promoting green development and creating humanistic culture. To promote green and low-carbon development. To promote the coordination of space for transport infrastructure and ecology; to implement projects to restore and enhance the ecology, to optimize and adjust the transport structure, and promote the clean, low-carbon, and efficient

			development of transportation energy and power systems. To strengthen the creation of humanistic culture, to meet the diversified and personalized needs of different passenger groups.
Guiding Opinions on Accelerating the Establishment and Improvement of a Green and Low-Carbon Circular Development Economic System	February, 2021	the State Council	Promoting the green development of transport infrastructure. Integrating the concept of ecological protection into the whole process of transport infrastructure planning, construction, operation and maintenance, making intensive use of land and other resources, reasonably avoiding spaces of national land with important ecological functions, and actively building green highways, railways, waterways, ports and airports
Action Plan for Carbon Dioxide Peaking before 2030	October, 2021	the State Council	Accelerating construction of green transport infrastructure. To implement green and low-carbon thought throughout the whole process of planning, building, operating, and maintaining transport infrastructure, reducing lifecycle energy consumption and carbon emissions.

			Carrying out green and low-carbon transformation of transport infrastructure. To boost construction of infrastructure such as charging piles, supporting power grids, and natural gas and hydrogen fueling stations through an orderly approach to improve public transport infrastructure in urban areas.
Opinions on Promoting Green Development under the Belt and Road Initiative	March, 2022	NDRC, MOFA, MEE, MOFCOM	Focusing on three sections, i.e. cooperation in key areas of green development, green development of overseas projects, and improving the support and safeguard system for green development. Covering 15 specific tasks, including green infrastructure connectivity, green energy, green transport, green industry, green trade, green finance, green technology, green standards, climate change, etc.

Situation regarding climate change as well as resources and environment growing increasingly severe, energy and environment now become the world's major concerns. Showing strengthen in the transport sector, China took the lead in developing its transportation infrastructure and witnessed rapid development of the new energy vehicle (NEVs) industry. The future transportation system covers infrastructure, automobile, energy, communication, big data, cloud computing, and artificial intelligence (AI), to name but a few, requiring all-round coordination of all units in the whole ecosystem.

New technologies and development modes brought new impetus to the industry, favorable for improving the efficiency of transportation operation and organization, energy consumption, pollution governance technology and total amount control. Green transport, in a word, is to integrate the concept of eco-environmental protection into the whole process of transportation infrastructure planning, construction, operation and management, to build a system with green structure, technology and management[6].

Stretching across Asia, Europe and Africa, countries along the Belt and Road are facing with a complex, diverse and interconnected eco-environment and a community of shared future for survival and development, due to their different geomorphic patterns, atmospheric circulation, water circulation, animal and plant systems and human activities. The eco-environment of countries along the BRI is characterized by sensitivity and cross-border transmission of pollution. Its East and West ends are respectively the fast-growing East Asian economic circle and the developed European economic circle, and the middle is the hinterland of a sensitive and fragmented continent that is rich in resources, and relatively fragile in its ecology. Major risks and challenges encountered by the countries along the Belt and Road in resources, environment and sustainability were global climate change, water resource crisis, desertification, cross-border pollution, poverty, natural disasters and the COVID-19 pandemic. Climate change and human activities have exacerbated the sensitivity of the eco-environment of BRI. To this end, the construction of BRI must not follow the past way of “treatment later", but to adhere to ecological conservation, protect the eco-environment, and build a green BRI in which man and nature live in harmony.

In 2015, China issued the *Vision and Actions on Jointly Building Silk Road Economic Belt and the 21st Century Maritime Silk Road*, clearly proposing to highlight the concept of ecological conservation, to increase cooperation in conserving eco-environment, protecting biodiversity, and tackling climate change, and join hands to make the Silk Road an environment-friendly one. President Xi Jinping has emphasized in many occasions that we need to deepen cooperation in the eco-environment area, to

practice the philosophy of green development and strengthen eco-environmental protection, aiming at building up a green Silk Road.

- In May 2017, at the Belt and Road Forum for International Cooperation, he proposed that "roposed that Cooperationreen Silk Road.n development and a way of life and work that is green, low-carbon, circular and sustainable. Efforts should be made to strengthen cooperation in ecological and environmental protection and build a sound ecosystem so as to realize the goals set by the 2030 Agenda for Sustainable Development".
- In April 2019, at the Second Belt and Road Forum for International Cooperation, it was again emphasized that "We need to pursue open, green and clean cooperation. The Belt and Road is not an exclusive club; it aims to promote green development. We may launch green infrastructure projects, make green investment and provide green financing to protect the Earth which we all call home".
- At the Leaders Summit on Climate held in April 2021, "China has also made ecological cooperation a key part of Belt and Road cooperation. A number of green action initiatives have been launched, covering wide-ranging efforts in green infrastructure, green energy, green transport and green finance, to bring enduring benefits to the people of all Belt and Road partner countries".
- In October 2021, at the Second United Nations Global Sustainable Transport Conference, President Xi reiterated that "China will continue to advance high-quality Belt and Road cooperation, strengthen infrastructure connectivity with other countries, and develop a green Silk Road and a digital Silk Road at a faster pace".

Transport infrastructure connectivity, represented by railways, highways, ports and airports, is viewed as the core and leading field of BRI cooperation. Occupying a large land area, and being complex in conduct projects, transport infrastructure is inevitably leaving certain impacts on the eco-environment. Therefore, promoting the green development of transport infrastructure is of great significance to constructing the green Silk Road, protecting global biodiversity and coping with climate change. This

report, with focus on green transport infrastructure and green commuting, shows the best practices of BRI's green transport development, providing useful reference for BRI participating countries.

Chapter II Green Transport Infrastructure

2.1 Railways

2.1.1 Ankara-Istanbul High-Speed Railway Project (Phrase II), Türkiye

2.1.1.1 Project Overview

With a total length of 533 kilometers, Ankara-Istanbul High-Speed Railway Project connects Ankara, capital of Türkiye, and Istanbul, Türkiye's largest city. The project, to be finished in 3 phrases, is the first electric high-speed train project undertaken by Chinese enterprises overseas (see Fig. 1). On July 25, 2014, when the project opened to traffic, the then Turkish Prime Minister attended the opening ceremony and took the first train. On July 27, 2014, the project was officially put into operation, narrowing the travelling time from Ankara to Istanbul from 10 hours to 3.5 hours, with its freight capacity lifted by 234%, and passenger capacity by 400%. This is the first high-speed railway in Türkiye, making it the 8th country in the world and the 6th in the Europe to enjoy high-speed railways. It is also the first high-speed railway built by Chinese enterprises aboard and the first time for China's high-speed railway construction technology going global, leaving a long-term and significant influence on the economic and trade cooperation between China and Türkiye[7]. China has established a joint venture composed of China Railway Construction (CRC) and China Machinery Corporation (CMC), and a syndicate of China Development Bank (CDB), Bank of China (BOC), Export-Import Bank of China (EXIM) and China Construction Bank (CCB), among others. An effective cooperation mode and mechanism was established hereby[8].

Fig. 1 Trail Operation of Ankara-Istanbul High-Speed Railway

(Photo from People.cn)

2.1.1.2 Measures and Achievements of Green Development

(1) Optimizing previous earthed system, to save costs and cut resource waste

Compared with China's domestic high-speed railway's earthed system, the technology utilized in the Ankara-Istanbul project applied the return line as the earthed wire. , which largely cut down the costs of engineering (see Fig. 2). Since the host country was unable to lower the cost of construction through mass production and standardization, if the same comprehensive earthed scheme as China adopted were taken, it was not a reality due to extremely high costs. The optimized scheme ensures the project's safe operation, and provides a solution for the shared system for communication, signal, power and traction power without reserved comprehensive grounding conditions. On the premise of meeting the relevant safety requirements of the European standard, the system achieves cost saving and resource waste reduction[9].

Fig. 2 Optimization Test of Ankara-Istanbul High-Speed Railway

(Photo from www.crcc.cn)

(2) Building up a regional "railway corridor" with local enterprises, making long-distance and low-carbon travel possible

Türkiye's total length of railways across the country was 13,000 km by 2021. By virtue of its position advantage, the government plans to extend the network to 25,000 km by 2023, to create a regional "railway corridor". During the past 14 years, Türkiye has invested USD 100 billion in transportation infrastructure such as railways, highways, airports and ports. It promised a faster pace of connectivity with other countries in the future, making Türkiye a global transportation hub. As per the Turkish Ministry of Transport, the passenger volume from Ankara to Istanbul is expected to increase from 10% to 78% after the railway's operation. The Ankara-Istanbul railway, after putting into operation, will cut down the time for long-distance trips, making high-speed railway the first choice of travelling and lessening the use of private cars. It helps reduce exhaust gas pollution and improve urban air quality. With the project, the travelling time from Ankara to Istanbul shortens from 10 hours to 3.5 hours, altering the mode of travelling for local people and making it possible to realize low-carbon travel in long -distance trips (see Fig. 3). The railway, connecting the two mega cities and driving the economic development, matters to Turkish people. High-speed railway is a better choice compared to buses, from

both the convenience of local residents and development of economy, as it is more comfortable, faster and more cost-effective[10].

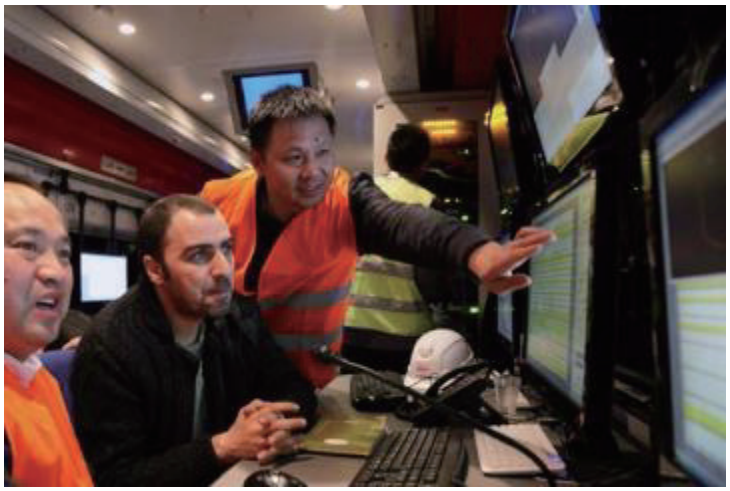

Fig. 3 Operation of Ankara-Istanbul High-Speed Railway

(Photo from Xinhua News**)**

(3) Protecting local environment, to create a green corridor getting over difficulties in construction

With slow development and insufficient coverage, Türkiye's high-speed railway did little damage to the local environment. To protect the environment, Chinese enterprises tried their best not to interfere with the local ecosystem. During the preliminary survey and investigation, they conducted the construction of railways at road sections with less species, avoiding the vulnerable areas to the best their ability, to protect the local environment from damage without affecting the project progress.

To conserve the local eco-environment, the project adopted different construction plans .according to the local terrain conditions. As the railway is facing mostly mountainous areas and complex geological structure, tunnels are supposed to be built for every 3 kilometers in average, with multiple bridges connected. There are 31 bridges and 34 tunnels in total along the project, in which nine bridges stretch over 3 kilometers, two over 5 kilometers. The longest tunnel marks 6 kilometers. The bridges, culverts and tunnels constructed by the Chinese enterprises accounted for 40%, seen as the most complicated

section (see Fig. 4). Other than the complex terrain, there are also many places of interest along the railway, which may be damaged by the vibration generated from construction or train operation, posing a huge challenge to the project.

Sticking to the concept of promoting the coordinated development of nature protection and engineering construction, all parties involved implemented the idea of green development. during the whole process. While overcoming construction difficulties, they respected and protected the nature, and did their best to build up the "green corridor". In combination of project construction and eco-environment conservation, the contractor designed the green works along the railway to protect the stability of roadbeds and ensure the safety of the train operation with a natural screen. Selecting greening plants according to local conditions has realized effective water and soil conservation and constructed the integrity of the ecosystem. Innovative technologies improved the resource use efficiency, reducing noises, sewage and pollution to the environment, to deliver energy conservation and emission reduction during construction.

Fig. 4 Tunnel Construction Survey of Ankara-Istanbul High-Speed Railway

(Photo from CCTV.com)

(4) Encouraging green mobility, shortening traveling time and promoting local employment

With the completion and operation of the project, employees traveling with the railway found less hours for long-distance commuting, less driving, and less waste of oil resources. Beyond that, Ankara-Istanbul High-Speed Railway speeds up the flow of talents in Turkey, greatly shortening the originally long commuting time, bringing more jobs to previously distant areas, which not only ensures income for employees, but provides talents for the enterprises' future development.

After the project's opening to traffic, distance between most cities in Türkiye and Istanbul is greatly shortened, which will attract more talents to reside in such mega-cities and inject unprecedented opportunities to become international metropolises to these cities.

2.1.2 China-Laos Railway Project

2.1.2.1 Project Overview

The China-Laos Railway is a strategic docking project between the BRI and Laos' strategy to convert itself from a landlocked country to a land-linked one[11]. As the only inland country in Southeast Asia, Laos boasts only a 3.5-kilometers-long railway. The line runs 1,035km, from the city of Kunming, southwest China's Yunnan Province, to Lao capital, Vientiane in the south. It is consisted of Kunming-Yuxi, Yuxi-Mohan, and Boten-Vientaine three sections (see Fig. 5), with nearly 62-kilometers-long bridges and 75 tunnels, stretching around 198 kilometers. Construction of the project started in December 2016, and completed and opened to traffic in December 2021.

The project, with Chinese investments and construction as the principal, adopting Chinese technical standards and equipment the whole line, is an overseas railway directly connected with the Chinese network. After its completion, the railway will, on the one hand, bring convenience and job opportunities to the Lao people, and boost local economic and social development with advanced transportation efficiency and level. Up to March 2022, over 400 cross-border freight trains were started through the railway's Lao section, totaling a volume of more than 250,000 tons. More than 100 items from Thailand, Cambodia and other countries were also transported to China through the line. It, on the other, will connect with the rails of Thailand, Malaysia and other neighboring countries in the future,

forming a railway system of both passenger and freight with large capacity and meet the common needs of countries along the line. Since its opening to traffic, the railway has largely promoted the economic and trade prosperity of China and Laos and enhanced the connectivity of the Asia Pacific region. Empowered with the Regional Comprehensive Economic Partnership (RCEP), the New International Land-Sea Trade Corridor and the Lancang-Mekong Cooperation (LMC), the China-Laos Railway will inject more new vitality into regional cooperation.

Fig. 5 Route Map of China Laos Railway

(Photo from imsilkroad.com)

2.1.2.2 Green Development Measures and Achievements

(1) Greening Works along the Project to Create a "Green Railway"

Composed of mostly mountains and plateau, the terrain of Laos is complex. The country is of subtropical monsoon climate, abundant in rainfalls throughout the year. The China-Laos Railway is a huge ecological treasure trove with beautiful natural environment and rich animal and plant resources. Over the past 6 years, contractors of the railway have been committed to harmony between human and nature, building a beautiful and pleasant "green corridor" along the project in advanced measures, such as water and soil protection, waste slag utilization, energy-saving and use of eco-friendly materials.

Ever since civil engineering, units of all phases have applied the concept of ecological conservation to the whole process of construction works, from designing, construction to acceptance, equating environment protection with engineering works, to make every effort to build a "green railway". As early as in the planning stage, environmental protection has been taken into consideration, pushing forward project construction abreast of environmental protection and taking targeted solutions for dust and noise reduction, sewage treatment and greening works. The construction made the utmost efforts in minimizing the impacts on the production and life of people, especially possible interferences to schools and medical stations, winning praises from the local people and the government.

During line investigation and selection, project designers collected data on-site, to hear opinions of authorities and directly affected people, so as to avoid the core, buffer zones and environmental sensitive points of natural reserves. They conducted extra in-field exploration of animal habitats (e.g. lizards), to assess, compare, and select solutions of route trends, tunnels length, river-crossing bridges, and stations on the basis of comprehensive geological conditions, environmental sensitive zones, traffic and urban planning and other factors. Such considerations were to minimize the interference to natural environment, settling a cost-effective, reasonable, eco-friendly and feasible scheme at last.

The China-Laos Railway, following the principle of "ecological priority" and "construction parallel with greening", innovated construction technologies to protect the eco-environment in Laos with flowers and grass. Constructors planted green vegetarians depending on different local conditions as per terrains, climate and plant cover along the line, to protect the stability of subgrade and slope, avoid soil erosion by rainwater and guarantee travel safety.

- In the northernmost of the Laos section, the Fifth Bureau (Group) Corporation of China Railway, the contractor, conducted greening on both sides of roadbeds and side slopes of tunnels, selecting plants of the Laos characteristics, such as jungle geranium, winter jasmine, and carpet grass.
- The fifth bid section constructed by Sinohydro Bureau 10 Co., Ltd (POWERCHINA), of the middle, runs through Vang Vieng, a tourist-oriented town in Laos. To ensure that local tourism

and scenic spots would be immune from the construction, the project management arranged personnel to check and maintain the sewage discharge system of the camp and set sealed waste container for scattered garbage. They also built sewage settling tanks and clean water pools in all concrete mixing stations and tunnels, requiring that polluted water produced during construction cannot be discharged until processed and met the standards.

- On the 6th section in capital city Vientiane, the contractor, the Second Bureau (Group) Corporation of China Railway, making good use of the environmental protection experiences gained in China, was committed to a greening principle that would ensure regular greening and various of flora all year round, proper distribution of trees and shrubs, adaptation to local conditions, and safe, controllable and science-based maintenance. With the original vegetation of both sides of the route, the project carried out an ecological restoration. to the largest extent.

During the greening process, China had ample discussions with the Laos side. To find out the common plants suitable for local subgrade, project staff followed the advice from local experts, Lao employees and nearby residents and then adopting transplantation instead of seedling cultivation. About 8.63 million shrubs and 55,000 trees were planted along the line, the greening area over 3 million square meters, making a “green railway” come true (see Fig. 6).

The Railway Vocational Technical College, a supporting project of the China-Laos Railway, aimed at helping Laos establish a mature railway system of management, technical talent training and capacity building. Yunnan Construction and Investment Holding Group Co., Ltd adopted in-situ conservation and transplantation measures to protect more than 100 native trees at the site of construction. Cutting the use of clay bricks, the contractor employed air-filled bricks, new partition walls and other eco-friendly insulation wall materials, to save energy, protect land resources, and inject a force of green development into a China-Laos community of shared future.

Fig. 6 Greening Works

(Photo from ce.cn)

(2) Protecting Asian Elephants, to Create an "Ecological Railway"

Yexianggu Station (see Fig. 7), one of the stations in the Yuxi-Mohan section, is located in Mengyang Town, Jinghong City, Xishuangbanna Dai Autonomous Prefecture, Yunnan. To avoid affecting activities and living conditions of wild elephants, special design has been done for the station, with Mengyang Tunnel at one end and the Xishuangbanna Tunnel the other, both stretching more than 10 kilometers. Such a mode, equivalent to putting a pipeline passing through the mountains (all constructions operated underground), did not cut across forests on the ground, decreasing changes to the living environment of animals and plants . Neither construction nor operation would disturb the normal moves of Asian Elephants.

With the concerted efforts of the local government and forestry departments, railways designers investigated the distribution and migration channels of Asian elephants, to settle the routes to keep distance from their main activity areas. By lengthening tunnels, replacing roads with bridges and setting isolation fences [12], Asian elephants were prevented from entering the route and getting injured. A good example is that, to better protect the elephants, the constructors optimized the foundation and superstructure of the protective fences, with the foundation changing from square to circular, fences from the assembled steel structure to the steel-wired grid. The railway has become a demonstration for the integration and coexistence of engineering construction and eco-environment protection,

minimizing the impact on the eco-environment, to enable a green development with beautiful ecology and symbiosis of all creatures.

Fig. 7 The Yexianggu Station (Wild Elephants Valley)

(Photo from yunnan.cn)

(3) Green Power Supply to Facilitate an "Eco-friendly Railway"

The China Laos Railway is an electrified railway. In its process of constructing the external power supply lines, the project made effort in protecting biodiversity and building a "green power grid". The external power supply project consists of two sections: one in China and another in Laos, the former is funded, constructed, operated and maintained by China Southern Power Grid (CSG) and the latter by Laos-China Power Investment Company. (LCPC). The project includes 2,220 towers and 936 km of overhead lines, most of which running through the mountains (see Fig. 8). In the past, erecting pylon towers usually meant first levelling the ground, which caused invasion and damage to the environment. However, in this project, CSG adopted tower foundations of unequal heights, determining the length of the four supports of the tower according to terrains. After construction, they planted suitable grass species to restore the local ecology [13]. To minimize disruption to the vegetation and preserve passages for animal migration, the contractor transported the tower materials by labor and horses [14], presenting due protection and respect to the local eco-environment.

Fig. 8 Power Line Passing through Xishuangbanna Forests

(Photo from csg.cn)

(4) Cultural Heritage , to Construct a "Colorful Railway"

A total of 11 stations were built at the China-Laos Railway China section, the designs of which were widely integrated with local and regional characteristics, ethnical features and historical culture. For example, the design concept of the Ning'er Station is "Ning'er, Home of Tea", whose roof fully shows the element of tea. Another one is the Pu'er Station, which boasts the "Ancient Tea Trade Route, a Post Stop in Yunnan", decorating its buildings with detailed folk patterns. The Xishuangbanna Station, known for its dancing peacocks and colorful clouds, modelling its grandeur roof like a peacock spreading its tail [15] (see Fig. 9)]. These designs, coordinating with and adapting to modern civilizations in local cultural elements and decorations, promoted a sound cultural atmosphere and deepen the concept of green development and natural protection.

Fig. 9 Pu 'er Station and Xishuangbanna Station

(Photo from People's daily, Xinhua News)

(5) Boosting Economy, to Achieve a "Way out of Poverty"

According to the resolution of the United Nations General Assembly, Laos has been in the five-year "preparation period" to break off from the list of the "least developed countries" (LDC). Laos is now facing a critical juncture of poverty alleviation. The China-Laos Railway will provide 110,000 job opportunities, cultivating a large number of engineers and industrial workers for Laos. Many Lao students studying in China will join in the construction, operation and maintenance of the project after graduation, making greater contributions to the industrialization and modernization of Laos in the future. The railway enables fresh agricultural products in Laos to be transported to China at the fastest speed, bringing actual benefits to farmers, who account for 60% of the country's total population [16].

2.1.3 Summary

Railway has been one of the biggest concerns among the BRI's infrastructure fields. Relying on its edges in technology and construction, China has expanded its cooperation in railway projects with the BRI participating countries and regions over the years. According to the 2020 Statistical Bulletin on China International Project Contracting, issued by the Ministry of Commerce, in 2020, the turnover of Chinese enterprises made in the railway construction projects (including metro, light rail and related public hubs), cooperated with the BRI participating countries, accounted for 30.7% of the total. Railway projects, normally featuring long lines, large span and exhaustive construction duration, especially when encountered with projects crossing different countries or regions , prone to facing complex and sensitive ecological and geological environments, should pay more attention to the impacts from route selection, land occupation, pollutant discharge, biodiversity, animal migration, and water system connection, among others. Therefore, from design to construction and operation, the whole process of the project requires particular watch on eco-environment impacts.

Green development has always been a part of the BRI railway projects, the whole process from construction to operation,. Integrated with eco-environment protection, the project designed construction plans and greening works according to local conditions, to reduce waste of resources and

protect biodiversity with innovative environmental protection technologies. Such measures avoided damage to the local environment, creating a green railway characterized by the harmony between man and nature and coexistence of all creatures.

The two cases in this chapter displayed the concrete practices of green railway construction. In building the Ankara-Istanbul High-Speed Railway Project, resources waste was reduced by optimizing the original grounding system. It created a regional "railway corridor", to make a long-distance and low-carbon travel possible. Different construction plans were carried out according to local terrain conditions, to create a "green corridor" with less project interference and more protection of cultural heritage. Adhering to the green development concept of low-carbon and environmental protection, the China-Laos Railway has fully investigated the possible environmental impacts of the project from survey and route selection to construction, delivering a fine integration of the railway and the nature. It cultivated green plants along the line in the light of concrete circumstances, to reduce soil erosion and accelerate ecological restoration. In skewing from wildlife activity areas, the project tried to minimize the impact of construction on the eco-environment. The external power supply project preserved passages for animal migration, standing for biodiversity. Ethnical characteristics and cultural heritage were also well combined with the concept of green transportation. As one of the most eco-friendly ways of transportation, railway helps to lessen long-distance bus travels and promote low-carbon mobility. In addition, during the construction of the above-mentioned two projects, the participation of local communities was fully considered, with opinions of local experts and environmentalists solicited, so that the green actions of Chinese enterprises could be truly recognized by the local people.

2.2 Highways

2.2.1 Peshawar-Karachi Motorway (PKM) Project, Pakistan

2.2.1.1 Project Overview

In 2015, China and Pakistan established the all-weather strategic cooperative partnership, which was led by the China-Pakistan Economic Corridor (CPEC) and centered on Gwadar Port, energy, transportation infrastructure and industrial cooperation, shaping a "1 + 4" economic cooperation layout [17] to drive the green and low-carbon development in Pakistan. In September 2016, China State Construction Engineering Corporation (CSCEC) undertook the Pakistan Peshawar-Karachi Motorway (PKM) Sukkur Multan Section. The project, since its completion, was referred to as the "green corridor", stepping up the construction of CPEC (see Fig. 10) and the stable development of China-Pakistan strategic partnership.

Fig. 10 China Pakistan Economic Corridor Map

(Photo from yidaiyilu.gov.cn)

With a total length of 392 km, the PKM Project (Sukkur Multan section) is the North-South transportation artery of Pakistan, starting from Sukkur, Sindh to the south, to Multan, economic center of Punjab, in the north. Being the largest transportation infrastructure project of the CPEC, it is also by

far the motorway with the highest design level in Pakistan, which boasts the only one with trees along the entire road and able to resist once-in-a-century floods [18] (see Fig. 11 and Fig.12).

Fig. 11 PKM Official Handing-Over Ceremony

(Photo from cscec.com.cn)

Fig. 12 PKM Project

(Photo from csci.cscec.com)

In December 2020, PKM officially handed over and opened to traffic, becoming the first two-way 6 lanes motorway with intelligent transport system in Pakistan. Completion of the project enabled a reduction of travel time from 11 hours to less than 4 hours, improving the traffic efficiency and promoting the economic development of Pakistan. It played a positive role in the connectivity of the two countries, officially launching the first year of modernization and IT application for Pakistan's motorways.

2.2.1.2 Green Development Measures and Achievements

(1) Greening Works along the Motorway

The PKM project is seated in an area of the temperate continental climate, with small precipitation and low humidity, of which 120 kilometers were of saline-alkali soils . Green plants are therefore hard to survive here. In conducting greening at roadsides, interchanges and building areas, it got rid of the difficulties in the scarcity of saplings and grass seeds resources, poor soil quality, and wide range of pest control. Along the artery, a total of 335,800 saplings and 5.53 million square meters of lawns were settled, making a greening area of 576,500 square meters (see Fig. 13).

Fig. 13 PKM Panoramas

(Photo from cscec.com.cn)

Specific measures taken to consolidate the environment include: (1) planting two rows of roadside trees, according to soil properties, on both sides, such as Indian lilacs, Indian banyan, buttonwood, black plums and arjun trees, erecting an ecological screen; (2) building up interchanges, besides the greening measures to roadsides, ornamental tree species were planted in patches, especially gum arabic, golden shower, crape myrtle, and great bougainvillea; and (3) for greening of the housing area construction, the choice was landscape saplings found in local, which mainly took ornamental small trees, shrubs with colored leaves and hedgerows [19].

(2) Improved Construction Technologies and Traffic System

Targeted and upgraded technologies were taken to accommodate to the high temperature and heavy-load traffic,. **First, the use of green and eco-friendly asphalt.** In the mix design of asphalt, the constructor applied SBS modified asphalt to improve pavement rutting resistance, by adopting coarse gradation (refer to the Chinese standard) and increasing the void ratio from 3%-5% to 4%-6%. Within an allowable range, the asphalt consumption designed took less oil content. Facing a maximum temperature up to 75 Celsius degree, the roadbed had to improve the softening point of asphalt and its temperature resistance performance with Chinese standards, to ensure that the asphalt would remain forming quality, rather than be softened under the high-temperature of 80 °C [20] (see Fig. 14).

Fig. 14 PKM Construction Site

(Photo from cscec.com.cn)

Second, better concrete quality. With the optimization of concrete mix as its core, the technology of slip form construction was adopted for guardrails and curbs because of the length of the line. To tackle with the high temperature, the constructor altered the way of unloading, installed refrigeration equipment to water for concrete, and applied the sunshade net onto cement tanks and mixer trucks, to prevent concrete water from losing too fast and improve its coagulability, thus saving materials, conserving energy and the environment.

Third, developed transportation system standards. Toll collection system, signals management, and other functions all achieved electronization and automation. Optical cables along the entire road help transmit real-time information caught by cameras to the control center, facilitating a comprehensive watch of the traffic and keeping eyes on safety [21]. It has achieved the maximum efficiency with the minimum social costs, reducing traffic inconvenience and environmental pollution and making a proper use of resources.

(3) A Green Corridor for Animal Migration

During its implementation, the project was committed to hold tight of the green concept, to protect the local ecology and ensure the migration of gerenuk and other wild animals. As agriculture relies heavily on irrigation here, and based on the habits and migration patterns, the constructor built 920 pipe culverts of more than 40 kilometers in selected areas with broad vision, flat ground and moderate soil. All these

culverts, in drawing suggestions from wildlife experts, environmental departments and local residents, were designed with local standards and integrated with the natural environment, becoming channels that are favorable for the movement, living, migration and reproduction of animals. They did help the wild animals with long-distance migration and adaptation to the changes of the external environment (see Fig. 15). In protecting biodiversity, they also gave full guarantee to the interests of local farmers and agricultural water safety, making a "green corridor" worthy of its reputation.

Fig. 15 Pipe Culverts Construction Site

(Photo from cscec.com.cn)

2.2.2 Phnom Penh-Sihanoukville Expressway Project, Cambodia

2.2.2.1 Project Overview

Cambodia Phnom Penh-Sihanoukville Expressway Project, invested by China Road and Bridge Corp. (CRB) with a Build-Operate-Transfer (BOT) model, was started in March, 2019 and trial operation was started in October 2022.. After its completion, the project would become the first expressway in Cambodia, connecting the capital city Phnom Penh to Sihanouk port, the largest seaport in the country. The traveling duration would be reduced to less than 2 hours from 5 hours. The two-way four lanes boast a total length of about 190 kilometers, with a design speed of 100 km/h, and a 24.5-kilometers-wide subgrade. The entire line was built with 6 interchanges, 3 service areas, 1 parking lot and 4 maintenance work areas [22]. The complete express would largely cut down the logistics costs, boosting the economic and social development [23]. The project is a successful docking between China's BRI

and Cambodia's "Rectangular Strategy", which will connect the capital's economic circle and the largest deep-water port of Cambodia, Sihanouk port, after its completion [24]. With natural conditions along the line, including terrains, landforms, waters and geology, all into considerations, CRBC conducted the development planning of main cities and towns, routes and road network s. The final route map is as shown in Fig. 16, the construction drawing is shown in Fig.17, and the effect diagram is shown in Fig.18., with 57-km-long sound insulation wall to prevent animals passing.

Fig. 16 Cambodia Phnom Penh-Sihanoukville Expressway Project

(Photo from cc-times.com)

Fig. 17 Project Construction Site

Fig. 18 Project Design Sketch

(Photo from mot.gov.cn)

2.2.2.2 Green Development Measures and Achievements

(1) Building an ecological sound barrier

In building the project, a total of 44 sound sensitive points were identified through site investigation and verification, including 1 school, 41 residential areas and 2 temples. Effective acoustic environment protective measures were adopted, mainly including tree belts for noise reduction, sound barriers, and setting no horn signs [25].

At the sound sensitive sections, i.e. residences and temples, the constructor planted tree belts to reduce noises by the roadside, following the requirements of owners and the existing prevention and control measures in Cambodia. The belt (see Fig. 19), with a total length of 35.09 kilometers, covered an area of 40,065 square meters, growing about 60,098 trees. Taking advantage of the 10-meters-wide space, the project planted one-year-old grafted seedlings of mango, cashew nuts, jackfruit, and redwood, among others. While at the section closing to the school area, a 430-meters-long block-type sound barrier was built (see Fig. 20). All sound sensitive areas were installed with no horn signs.

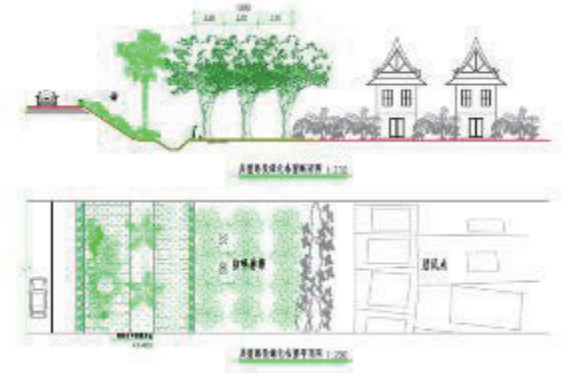

Fig. 19 Noise Reduction with Plants

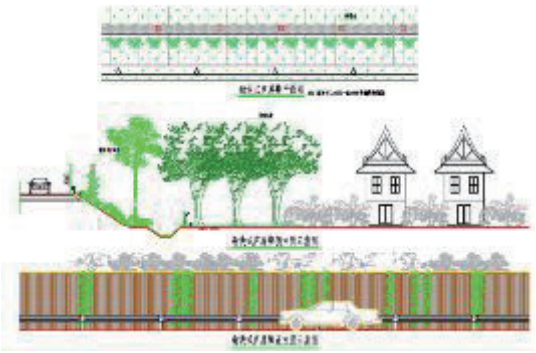

Fig. 20 Block-type Sound Barrier

(Photo from the Environmental and Social Impact Assessment Report)

Specific measures have been taken during the process of construction. Low-noise machinery, equipment and process were employed. Vibration damping bases were installed for fixed mechanical equipment with large vibration. The project team also strengthened the maintenance to keep sound

operations, reducing noise sources from the root. Management was well taken care of. The constructor arranged a proper time range for construction, to avoid operations conducted within 150 meters of residential areas or between 22:00-6:00 (night hours). No piling was permitted at night. Sampling monitor was carried out for sensitive points close to the construction area, taking temporary measures for noise prevention, with special efforts made for schools along the project: to follow the environmental quality standard for noise Category 2 (lower than 60 dB at day-time, 50 dB at night-time). Construction should keep away from the examination time. ,In line with the labor and health standard, the contractor should have a reasonable arrangement of the workers' working hours, to operate the equipment in turn, or to work in the high- or low- noise environment in an alternate manner. Workers should have time to recover hearing, and protective measures should be taken for the machinery operators.

(2) Constructing Special Passages to Protect Vegetation and Wildlife Habitats

Cambodia is one of the countries with the richest biodiversity in Southeast Asia, with as many as 8,260 species of plants and 10% of them unique, more than 250 species of amphibians and reptiles, 874 species of fish and 500 species of birds [26]. During its construction, the project engaged in the protection of fish passage and animals from the National Forest Park. Protective measures were taken for fish and reptiles.

The project runs through 6 rivers, all of which are important fish producing areas . To conserve fishery productivity, the contractor restored fish channels and ensured headroom of bridges for fishing boats to navigate. Specifically, the project team created fish habitats for the rivers under 12 bridges, carrying out ecological treatment, setting up pine pile embankment, and building a bottom of the ecological pool (see Fig. 21). For reptiles such as turtles, lizards and snakes, a 21-km-long barrier was erected to prevent them from entering and getting hurt from the project construction area. 27 animal protection signs were placed along the expressway. As some sections are the active areas of Asian elephants, the clearance

of bridges and culverts were enlarged to facilitate a safe passing. More intensified and higher barriers were set to prevent elephants from entering the project road [27].

To avoid the project's interference on the existing wildlife passes, a series of measures to protect wildlife was taken: animal passages were built along with bridges and culverts and vegetation restored. Fences were made thicker to prevent wild animals from crossing and getting injured. Warning signs were installed to remind drivers of wild animals. Publicity was also conducted for people living in the surrounding areas. All these measures were taken to ensure that wild animals would be well protected.

The project's area is rich in vegetation. The construction team mapped out the green line and the red line of environmental protection (see Fig.22), strictly prohibiting destructions to plants beyond the requested land range. Especially for the trees with diameter at breast height (DBH) wider than 20 cm and rare seedlings, the team has carved out a special area with the green line for protecting the environment.

To prevent trees from illegal felling, the contractor took many measures. They placed signs warning prohibiting illegal felling of forest land at the main entrance and exit of the expressways. At the protective road sections, single-post signs of deforestation control were set. Moreover, noise-reducing forests were built in noise-sensitive areas, production water discharged after three-level precipitation, and earthwork and construction procedures optimized to control dust, to promote the harmonious coexistence of the project and nature, joining hands with the local community to protect lucid mountains and clear waters.

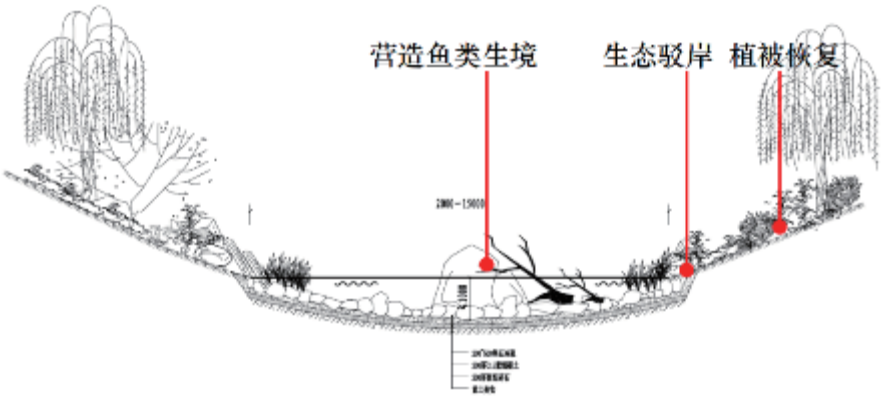

Fig. 21 Fish Habitat River Restoration

(Photo from crbc.com)

(3) Applying Eco-friendly and Energy-saving Technologies, to Build Green Buildings in the Service Area

There were 6 interchanges, 3 service areas, 1 parking area and landscaping areas at the starting and ending locating at the expressway. Greening works of these interchanges strictly followed the principle of environmental protection. Kampong Speu, Traeng Trayueng and Kampong Seila, with good natural conditions, were cut off artificial traces, preserving the original vegetation and landscape stones to reflect the local cultural features. Vertical greening was employed for other interchanges, to improve the vegetation and eco-environment at local.

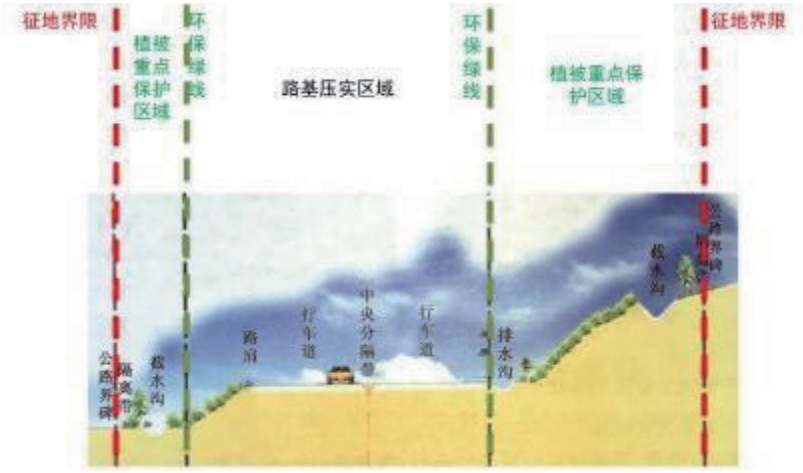

Fig. 22 Environmental Protection Greening

(Photo from crbc.com)

Both the Kampong Speu (see Fig.23) and Traeng Trayueng interchanges (see Fig.24) were located in the idyllic scenery section, enjoying well-grown original vegetation worthy for preservation. The former expected to create a vertical space of arbors, while the latter, with one brook, could be designed as a rainfall garden, to deliver a wetland landscape. Economic forest seedlings were planted in other areas, with sunflowers and Persian chrysanthemum on the slopes, which not only added up to the greening, but also reflected the original rural features.

The Kampong Seila Interchange (see Fig.25) , situated at the hilly mountain forests, boasted fantastic vegetation in the ramp and special value for conservation. t should be protected before the construction. With such an original setting, the design was mainly based on the previous landscape without interference with the local vegetation. Only a small number of ornamental trees were added as ornamentals, to conserve the original vegetation and increase the good view to the largest extent.

Fig. 23 The Kampong Speu Interchange

Fig. 24 The Traeng Trayueng Interchange

Fig. 25 The Kampong Seila Interchange

(Photo from tpri.org.cn)

In consideration of Cambodia's economy and population, the project optimized the construction area as much as possible on the premise of meeting the using functions of the expressway, which was largely decreased compared with the design value of similar projects. The vegetation and greening area inside the field zone was improved, to achieve a low-carbon and eco-friendly project. All engineering of the service area was equipped with Grade III steel, to protect arable land. Clay products were not allowed in structural maintenance. Energy-saving lamps were put to use inside all buildings, as the basic light sources accordingly. While in public areas, such as in the corridors, lamps and lanterns chosen were mainly energy-saving fluorescent flat lamps or ceiling ones. The constructor also found reasonable way to build the power distribution system, with the box placed in the service center, to reduce the radius of power supply and reduce line losses [23].

The water recycling in the service area also drew special attention. Gathering domestic sewage in the station area to the internal treatment station, the project team delivered effluents that met Level A standard as specified in China's *Discharge Standard of Pollutants for Municipal Wastewater Treatment Plants*, i.e. the quality could be equivalent to urban landscape water discharged into rivers and lakes with small dilution capacity, or the general reuse water. The effluent water can be used for greening and flushing in public toilets, which can realize water recycling and save water. To reduce solid waste production and improve the efficiency of waste treatment, the service area collected and

treated garbage in a classified manner, types including recyclables, hazardous waste, food residues and others.

2.2.3 Summary

Highway projects play an important role in the infrastructure field under the Belt and Road initiative. According to the 2020 Statistical Bulletin on China International Project Contracting, issued by the Ministry of Commerce, the turnover of Chinese enterprises of highway projects in the BRI participating countries accounted for 38.4% of the transportation sector in 2020, which took the largest share, mainly located in Asia and Africa. The coverage of highway projects was usually not as wide as railways, however, as most countries and regions along the BRI are situated in sensitive areas of climate and geological changes, the natural environment is complex, the eco-environment diverse and fragile, causing universal challenges that environmental protection should be strengthened during the highway construction process.

Similar to railways, highway projects are also long-distance transport engineering and compounded with sensitive ecological areas, facing certain eco-environmental challenges in route selection, animal migration, land occupation, and noise impacts. **(1) Site and route selection.** During the route selection, the project needs to consider a rational use of existing traffic corridors to reduce the secondary division of the ecosystem and land occupation. **(2) Routes to avoid the migratory passageways.** The project needs to analyze the impact on the activities of local wild animals and migration corridors, to avoid their main areas of activities. Measures such as building animal passage tunnels, replacing roads with bridges, setting up isolation fences and sound and light barriers could be taken. **(3) Protect the local ecosystem.** Before the construction, the project can draw a red line to minimize the felling of trees and destruction to the green space. **(4) Reduce the noise impact**. Sound barriers are recommended to be built to abate noises. As the impact of global climate change looming large, railways and motorways established along the coastal lowlands or in the alpine areas, should give more thoughts on the rising temperature and sea levels.

Taking the two projects in this section as example. The PKM project, Pakistan, achieved the goal of energy conservation and environmental protection by improving the construction technology and developing intelligent transportation system standards. The constructor realized greening of the entire line. In building pipe culverts, they created green corridors for animal migration, integrating modern transport with the living circumstances of wildlife. The Phnom Penh-Sihanoukville Expressway Project, Cambodia, built an ecological sound barrier, through the tree belts, to protect the sound environment. The project constructed specialized channels for fish and wild animals, to protect their habitats; and it also adopted environmental protection and energy-saving technology, and stereo greening, to conserve the ecology. Following the concept of "restoration while construction", the project was inclined to minimize the impacts to environment.

2.3 Bridges and Tunnels

2.3.1 Pulau Muara Besar Bridge in Brunei

2.3.1.1 Project Background and Overview

The Pulau Muara Besar Bridge (PMB bridge) contracted by China Harbour Engineering Company Limited., designed by CCCC Highway Consultants CO.,LTD and built by CCCC Second Harbor Engineering CO., LTD. has officially completed its construction on May 18, 2015. This bridge will serve as an important traffic artery connecting Daerah Brunei Muara and Pulau Muara Besar. It is also the first grand bridge spanning the sea. PMB bridge is a dual-carriageway four-lane highway bridge with a total length of 5,915 meters and a design speed of 100km/h. The construction work includes a 2,680-meter long and 23.6-meter wide inter-island bridge, a 310-meter long connecting line to the west and a 2,925-meter long connecting line to the east (see Fig.26) .

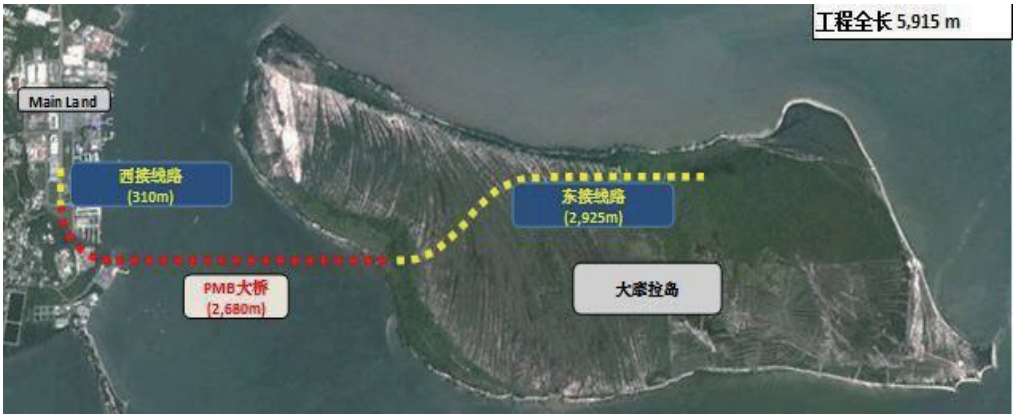

Fig. 26 Map of Brunei PMB Bridge

(Picture from *sohu.com*)

In May 2018, the Pulau Muara Besar Bridge opened to traffic. The Bridge is a continuous rigid frame bridge. Unlike the more common types like the suspension bridge and cable-stayed bridge, the PMB Bridge adopts a distinct box girder structure which makes it a unique scene across the sea (see Fig.27). The box girder structure enables the bridge to use local materials and adopt industrial construction while at the same time enhance its durability and overall beauty. In addition, this structure is well-developed in terms of designing theory and construction technology. It also excels in adaptability, thus making it the optimal construction scheme for PMB Bridge.

Many innovative technologies have been adopted in the design and construction of the project. During the construction of the bridge, the project team has overcome various difficulties such as the harsh climate environment in Brunei, and addressed many technical problems. The completion of the bridge has ended the history of Pulau Muara Besar being an island completely isolated from Brunei mainland. It is of great significance for Brunei to increase investment and build the island into a world-class petrochemical industrial park. It will also promote the urban development of Brunei and the oil and natural gas development of the island [27]. On December 3, 2021, the PMB Bridge project won the ASEAN outstanding engineering achievement award at the 39th ASEAN Engineering Organization

joint meeting. The award aims to recognize outstanding engineering technologies that have made significant contributions to the engineering progress and quality of life in the ASEAN region.

Fig. 27 PMB Bridge in Brunei

(Picture from China Construction Network)

2.3.1.2 Green Development Measures and Achievements

(1) Optimization of Construction Technology and Resource Conservation

After the commencement of the project, the team encountered many obstacles. The construction team have overcome multiple difficulties such as poor construction environment, complex geological conditions, and lack of material and equipment supply. They have successively solved technical problems such as the construction of offshore pile foundation with a high slenderness ratio and the construction of large concrete pier caps in tropical areas. They have researched and developed a number of scientific and technological innovations such as the short line installation of bending and folding bridge erecting machine and the construction of small curvature ultra-high cross slope box girder.

In the stage of bridge pile foundation construction, faced with unfavorable geological conditions, the project team drew on mature experience both at home and abroad, focused on the research of pile foundation wall protection type, hole forming process, mud performance, etc., and thus developed key technologies for offshore pile foundation construction with super slenderness ratio, successfully solved the difficulties of pile foundation construction, and improved the solidification performance of soil.

The project has greatly saved construction materials for green construction of transportation infrastructure [28].

In addition, during the construction of the approach bridge on the west side, due to topographic constraints, the approach bridge on the west side is located on the horizontal curve line with a radius of 550 meters, while the bridge deck needs to make a sharp turn of nearly 90 degrees, which is rare in the history of bridge construction in the world. Faced with this difficult mission, the staff of CCCC Second Harbor Engineering Co., Ltd. creatively applied "the construction technology of installing small curvature ultra-high cross slope box girder with short line method using bending and folding bridge erecting machine", which solved the problems in the construction of the curved section of the bridge. By optimizing the construction technology, the team maximized the traffic efficiency, saved resources, and reduced environmental pollution[29] (see Fig.28) .

Fig. 28 Construction of the PMB bridge in Brunei

(Picture from CSCEC official website)

(2) Boosting the Vitality of Green Traffic in Pulau Muara Besar

Pulau Muara Besar Bridge connects the Bandar Seri Begawan City and the neighboring Pulau Muara Besar (see Fig.29) . A few years ago, the sparsely populated Pulau Muara Besar is now the location of the largest joint venture project between China and the Brunei—the refining and chemical project in Pulau Muara Besar by Hengyi Petrochemical (Brunei). The construction of the bridge coincides with the important stage of implementing the Belt and Road initiative and the critical period of Brunei's accelerated economic development. It contributes to Brunei's economic and social development. With the completion of Brunei's first inter-island bridge, Pulau Muara Besar Bridge will end the history of Pulau Muara Besar being an island completely isolated from Brunei mainland. It is of great significance to Brunei's urban development and the development of oil and natural gas resources of Pulau Muara Besar. It also serves to promote the development of green transportation along the bridge.

Fig. 29 Panoramic view of Brunei Bridge

(Picture from CCTV)

The bridge has a total length of 2.68 kilometers and was completed in May 2018. The completion of the bridge enables the Western Pulau Muara Besar to connect with the eastern islands, which means Pulau Muara Besar is no longer completely isolated from Brunei mainland. It is of great significance to the urban development of Brunei, the increase of investment and the construction of a modern petrochemical industrial park in Pulau Muara Besar. The convenient transportation between cities promotes the economic and cultural exchanges of various places. The opening of the bridge saves the

commuting cost, reduces the waste of traffic resources, making positive contributions to the protection of the environment.

(3) Protecting the Vegetation Around the Island to Build a Green Corridor

The concept of green development has always been adhered to during project construction. In order to protect the green vegetation around the bridge and reduce water and soil loss, the project team has made every effort to protect the surrounding vegetation and soil as much as possible and increase the survival rate of plants (see Fig.30) according to the characteristics of local natural geographical environment and climate and the living habits of plants along the island. To protect biodiversity in the affected areas, the project team transferred and graft the vegetation, selected the plants that are relatively easy to cultivate, and specially built the isolation belt for vegetation protection. The team fully consulted the suggestions of plant experts, local gardens bureau, local environmental protection bureau and local residents on the selection and planting scheme of vegetation, so that the project serves to not only protecting the ecological environment, but also fostering a good living environment for local residents with a green corridor [30].

Fig. 30 Brunei PMB sea crossing bridge

(Picture from *sohu.com*)

2.3.2 Pelješac Bridge Project in Croatia

2.3.2.1 Project Background and Overview

Although Croatia has a small population, there is a huge traffic demand. As Croatia is located along the Mediterranean coast, crossing the Mali Ston Bay of the Adriatic Sea has become one of the traffic problems of the country. The Pelješac Bridge is the largest transportation infrastructure construction project since the establishment of diplomatic relations between China and Croatia. It is a 2,440-meter long and 22.5-meter wide highway cable-stayed bridge over the Mali Ston Bay of the Adriatic Sea in the south of Croatia, connecting the mainland of Croatia and the Pelješac Peninsula. The Chinese enterprise consortium led by China Road and Bridge Corporation won the bid and started construction in 2018 (see Fig.31 and Fig. 32)).

Fig. 31 Geographical location map of the construction area (red area refers to the city of NEM in Bosnia and Herzegovina, which separates Ploče and Dubrovnik in southern Croatia)

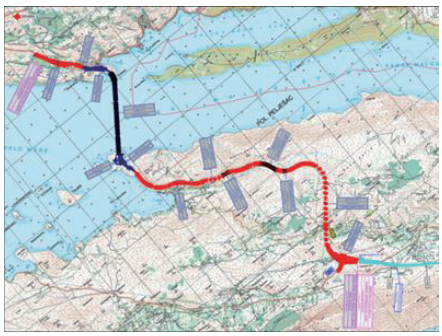

Fig. 32 Route map of Pelješac Bridge and its connecting line

Due to historical reasons, Dubrovnik Neretva Province in the southernmost part of Croatia is divided into two parts by the small town of Neum in Bosnia and Herzegovina. To go south along the coast to the famous Croatian tourist city of Dubrovnik and other places, one has to pass through the "Neum Corridor", leaving Croatia, entering Bosnia and Herzegovina, leaving Bosnia and Herzegovina and re-entering Croatia, a roundabout journey which is about 20 kilometers in length. It is a long-cherished wish of the Croatian government and people to build a bridge across the sea connecting the northern and southern territories.

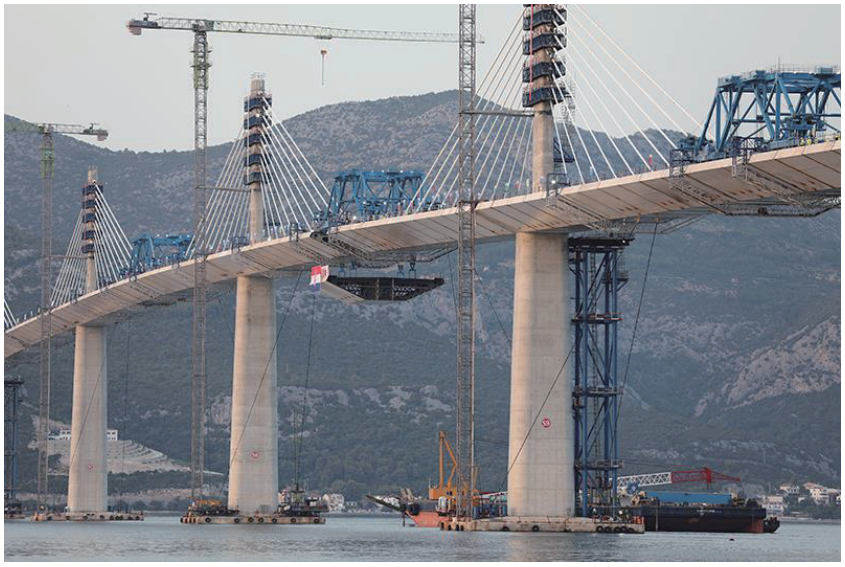

Fig. 33 Closure of Pelješac Bridge

(Picture from Xinhua News Agency [33])

The Pelješac Bridge was successfully completed in July 2021 and opened to traffic in June 2022 （see Fig.34 and Fig.35). After the completion of the Pelješac Bridge , all the territory of Croatia will be connected, eliminating the need to cross the border with Bosnia and Herzegovina and go through time-consuming and costly customs procedures in freight transportation. It also shortens the time it takes to supply food to the south and makes emergency medical transportation possible. The Pelješac Bridge will also greatly facilitate travel for the local population, give a strong boost to local tourism, improve the current situation in southern Croatia, where tourism relies mainly on air and ferries and is severely

affected by strong winds in winter, and expand tourism operations to the whole year instead of the current summer mode. The project has played an exemplary role in the practical cooperation between China and Europe and is highly praised as “a bridge of friendship, reunification and people's livelihood under the framework of the Belt and Road Initiative".

Fig. 34 Croatian Prime Minister Plenković attended the closing ceremony

(Picture from China Road and Bridge Second Highway Bureau, Thepaper [33])

2.3.2.2 Green Development Measures and Achievements

The Pelješac Bridge project is not only the largest infrastructure project undertaken by China in Croatia, but also the first major project funded by the EU and implemented in EU’s territories adopting EU standards. EU funds cover 85% of the project cost. Building materials and environmental protection requirements shall comply with EU standards, especially the steel structure of the bridge shall meet the highest European standards. Moreover, strict environmental protection standards shall be observed to avoid environmental pollution and ecological damage. The mud generated during piling shall be transported to the designated place for discharge. The project cooperated with 65 global equipment and material suppliers from Croatia, Germany and Spain and etc. From the bidding, preliminary preparation and implementation process, the project strictly followed the concept of green environmental protection, strictly complied with local laws and regulations, and strictly controlled the construction quality of the project.

(1) High Tech, All-Round Waste Recovery and Treatment

In terms of on-site construction, a “secondary sedimentation tank” shall be provided on the ship during the pile foundation construction. The mud after drilling is pumped into the hole to form a reverse circulation after two times of sedimentation. Finally, the pile foundation drilling slag is transported to the designated sea area 20 nautical miles away by the bottom barge for discharge, so as to prevent any disturbance to the bottom mud and to the original ecology (see Fig.35). At the same time, GPS and other accurate positioning and path tracking systems are installed on the slag carrier to standardize on-site operation, making sure that the mud is transported to the designated site and minimizing the pollution to the coastal water quality.

Fig. 35 Discharge of drilling slag by ships in designated sea area

Fig. 36 Installation of oil boom to prevent oil leakage

The oil tanker shall be installed with protective measures such as the oil booms to prevent pollution caused by oil leakage from construction ships (see Fig.36).

Fig. 37 Environmental friendly self-priming sand washer

The local environmental friendly self-priming sand washer shall be purchased for the steel box girder sanding equipment to increase the reuse of steel sand and avoid environmental pollution caused by the scattering of steel sand (see Fig.37).

Fig. 38 Regularly cleaning of the precipitates of the purifier by the third-party professional company

In the living area, a special treatment device for domestic sewage is set up, and a local professional company is employed to clean the sewage every week (see Fig.38).

Fig. 39 Asphalt overlay for the parking area of concrete tank truck to prevent oil leakage from polluting the land

Fig. 40 Oil water separator set in concrete tank car parking area

The road surface of the tank car parking area shall be poured for drainage, and the oil separator shall be installed at the end of the drainage channel to collect the waste oil on the vehicle and prevent the oil leakage of the tank car from polluting the soil (see Fig.39 and Fig.40).

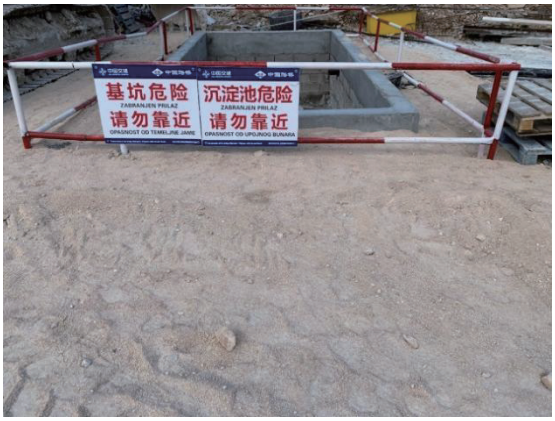

Fig. 41 Sedimentation tank for four stage sewage

A new sedimentation tank is built in the mixing station (see Fig.41) to ensure that concrete sewage is effectively purified and meets the discharge standard. A drainage ditch is built near the mixing station to prevent the sewage from flowing into the sea.

(2) Strict Implementation of Garbage Classification Requirements

In terms of on-site garbage classification and treatment, the methods of factory prefabrication, ship transportation and on-site assembly are adopted. Purification devices are installed in the living area, while garbage classification is strictly implemented and professional treatment is carried out regularly.

Fig. 42 Classified collection of domestic garbage

Fig. 43 Classified collection of construction waste in the construction area

Fig. 44 Classified collection and storage of hazardous wastes

Fig. 45 Garbage collection points for epidemic prevention and control

Domestic garbage, construction garbage, hazardous garbage and epidemic prevention wastes shall be classified (see Fig.42, Fig.43, Fig.44 and Fig.45). Classified garbage bins shall be set at the fixed points

of each construction pier. In particular, special storage points shall be set for construction garbage such as waste wood, waste plastics and waste steel bars, as well as hazardous garbage such as waste paint cans, waste oil residues, masks and protective clothing. All these garbage shall be recycled and transported in time working with local professional environmental protection companies.

Fig. 46 Classified storage and centralized treatment of construction waste by professional companies

Fig. 47 recyclable mobile toilets are set at the construction site

Classify and store construction wastes to ensure that the construction site is clean and efficient. Recyclable mobile toilets shall be set on the site to avoid human pollution (see Fig.46 and Fig.47).

(3) Protection of Biodiversity

In order to avoid the damage caused by huge noise to marine organisms, the construction team has adopted bubble curtain noise reduction measures after many innovations and reforms. A layer of dense bubbles is wrapped around the steel piles, effectively blocking the sound transmission channel with

external seawater (see Fig.48). The noise blockage of the bubble curtain noise reduction process reaches more than 97%, ensuring that the surrounding organisms are not disturbed [33]. Another function of the bubble curtain is that the bubbles produce disturbance, sound and low-frequency oscillation in the water during the discharge process, which has an intimidating effect on marine animals, thus keeping them away from the construction area to avoid harm (see Fig.49). After four months of steel pipe pile driving, the ecology of the construction sea area was not affected. Oysters with extremely high requirements on water environment still grow normally at the place less than 400 meters away from the pile position.

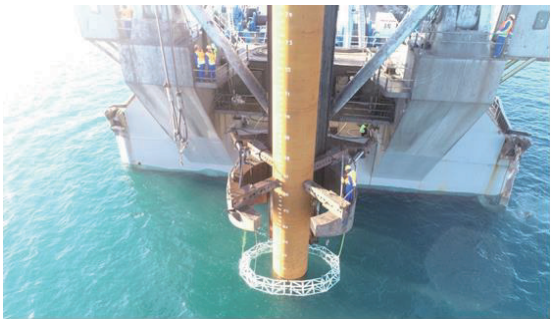

Fig.48 Bubble curtain

Fig. 49 Actual effect of bubble curtain

During the drilling construction, the secondary sedimentation of the drilling slag is carried out by the sedimentation vessel and the filtered water is recycled. The drilling slag is transported to the designated sea area by the bottom barge for discharge. Measures such as oil booms shall be provided for each ship to ensure good water quality in the construction sea area and reduce damage to marine organisms.

2.3.3 Karnaphuli River Tunnel Project in Bangladesh

2.3.3.1 Project Background and Overview

As is put by the person in charge of the Bangladesh Bridge Bureau, the construction of tunnels has always been the dream of the people of Bangladesh. Bangladesh has become one of the most backward countries in transportation construction in the world due to its dense population, dense water network and backward economy. Even Dhaka, the capital, has only more than 60 traffic light intersections [34]. Therefore, strengthening transportation construction is indispensable for the country to boost its development. Karnaphuli River Tunnel Project in Bangladesh contracted by China Communications Construction Co., Ltd. kicked off its construction on December 5, 2017 [35-36] and the progress of the project reached 96% in February 2023.. The project is designed and constructed according to Chinese specifications, with two carriageways, four lanes, a design speed of 80km/h and a total length of 9293 meters. The construction includes a shield tunnel, a bridge, a subgrade, and a temporary wharf, etc. The total length of the tunnel crossing the Karnaphuli River is 3315 meters and the diameter is 11.8 meters, of which the shield section is 2,450 meters long. It is the largest shield highway tunnel project in China. The tunnel will support the road connection of Dhaka, Chittagong and Cox's Bazar as well as the connection of Asian highway network. The project, located at the sea entrance of the Kanapuli River in Chittagong City, is the first underwater tunnel in Bangladesh. It connects the East and West banks of the Kanapuli River through the tunnel under the river. It will drive the development of the East Bank of the kanapuli River and achieve the development goal of "one city, two towns" (see Fig.50). Upon completion, the driving distance from Chittagong airport to the industrial park will be shortened from 4 hours to 20 minutes, which will greatly reduce the fuel consumption of vehicles, reduce vehicle exhaust emissions and promote energy conservation and emission reduction. The project is an important part of the China-Bangladesh-India-Myanmar Economic Corridor. Its completion will not only improve the traffic conditions in Chittagong City and boost the economic development of

Bangladesh, but also help improve the Asian highway network and enhance the interconnectivity between Bangladesh and neighboring countries.

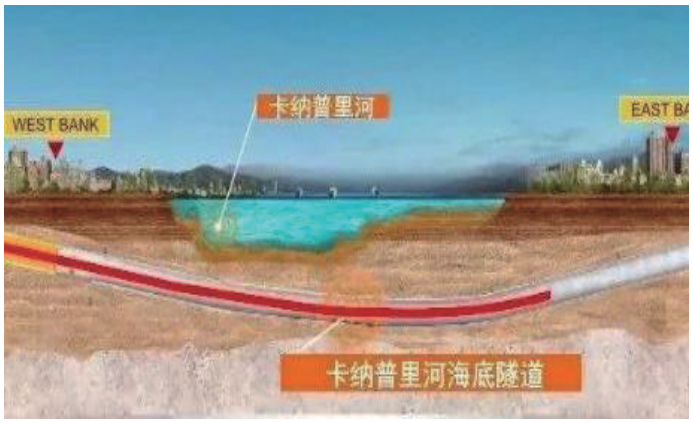

Fig. 50 Design rendering for the tunnel

(Picture from Official Website of CCCC)

2.3.3.2 Green Development Measures and Achievements

(1) Building a Standardized and Environmental-Friendly Project Camp

The project camp construction fully considers peripheral public safety as well as the geographic location and terrain characteristics, and is reinforced by hydraulic reclamation, with scientific overall planning and layout, complete functional areas and reasonable zoning (see Fig.51). The construction of the project camp complies with the environmental protection standards and is equipped with sewage treatment equipment, which can effectively treat the domestic sewage generated by the project and help improve the ecological environment while achieving energy conservation and emission reduction during the construction [37].

Fig. 51 Aerial view of the project camp

(Picture from Official Website of CCCC)

(2) Green Concrete Proportioning

At the beginning of the project, a complete set of test system was established with test rooms that cover more than 600 square meters, including concrete rooms, mechanics rooms and other functional rooms and advanced industrial instruments and equipment. In order to effectively control the quality of "the proportion of wet area in the main structure of open cut tunnel", the laboratory adjusted the concrete mix proportion used in the main structure through data analysis and instrument detection, reducing the adverse effect of large wet area caused by cracks in the main structure [38], which not only promoted the green use of concrete but also ensured the performance of concrete while reducing the amount of cement and the consumption of natural resources and energy. Meanwhile, the safe service life of concrete is improved with the waste and secondary pollution caused by repair or removal reduced and the pollution to the surrounding environment of the project minimized (see Fig.52).

Fig. 52 Project construction

(Picture from Official Website of CCCC)

(3) Innovative Technology for Green Construction

The mud water balance shield machine independently developed by China Communications Construction Co., Ltd. is used in the construction. This is the first large-diameter slurry balance shield machine exported by China. Its green environmental-friendly pipeline extension device solves the environmental pollution problem of slurry overflow in the tunnel. In addition, the shield machine has a high degree of automation, one-time tunneling, and is not affected by the climate. It is an energy-saving, efficient and environmental-friendly equipment, which not only accelerates the construction speed, but also reduces the environmental disturbance of the construction (see Fig.53).

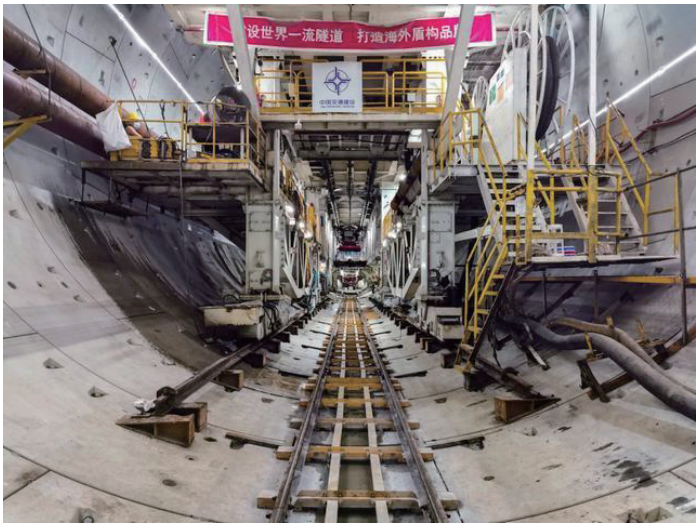

Fig. 53 Completion of tunnel construction

(Picture from Official Website of CCCC)

2.3.4 Summary

Bridges and tunnels are important projects for interconnectivity under the BRI Initiative. As many BRI countries are located in mountainous or marine areas, the construction of bridges makes the natural graben accessible and makes it possible to cross mountains and seas.

During the construction and operation of the bridge and tunnel projects, the environmental problems involved may include: first, the protection of large-scale water areas. The project can make full use of modern information technology, high-tech environmental protection equipment and other optimized construction technologies, develop and use green materials, reduce pollution discharge and improve the treatment capacity of waste water in order to reduce the pollution to the water area. Second, if the bridge is built with too many piers, the river section will be overloaded and the water flow will be accelerated, which will affect the migration of fish. If the bridge is too wide in width or too low in height, it will increase the area of the shadow area, causing stress effect and barrier effect to animals. Third, noise pollution of water body will also have an major impact on the normal activities of aquatic organisms, especially marine organisms. Therefore, special attention should be paid to reducing noise pollution of water body and protecting biodiversity during construction. In addition, the surrounding vegetation and soil shall also be protected according to the local climate, topography and geology.

In the project of Pulau Muara Besar Bridge, the difficulties brought by climate, topography and geology and offshore construction were overcome through innovation and optimization of construction technology and the goal of resources conservation and the improvement of traffic efficiency are also achieved. During the construction of the project, the vegetation around the island will be protected and a green corridor will be created by setting up vegetation protection isolation belt, transferring and grafting vegetation, soil protection and other measures. During the construction of the Pelješac Bridge Project in Croatia, the wastes and sewage generated in the construction of the project are recovered and treated by means of GPS and other information systems, high-tech environmental protection equipment, third-party professional companies and so on. In addition, strict waste classification and regular

professional treatment are also implemented to reduce pollution of the environment by human activities. With well-developed local farming and tourism industries, scientific noise reduction measures are taken to reduce the impact on marine life and protect biodiversity. The project has achieved "zero safety accident, zero defect of quality, zero pollution of environment and zero COVID infection" through all-round control of the sea area, backyard processing area on the land, office area and living area and other measures to promote full coverage of green construction and environmental protection management. During the construction of the Karnaphuli River Tunnel Project in Bangladesh, a standardized and environmentally friendly project camp was built to effectively treat domestic sewage and achieve energy and environmental conservation. A full set of testing system was established at the beginning of the project, and a laboratory was set up to study green concrete ratios to reduce the consumption of natural resources and energy while reducing waste and secondary pollution caused by repair or demolition. At the same time, new construction technology was innovated and energy-saving and efficient environment-friendly equipment was developed to address environmental pollution from mud and water overflowing in the tunnel, which brought green and economic benefits to the enterprise while speeding up the construction.

2.4 Port Project

2.4.1 Piraeus Port Project in Greece

2.4.1.1 Overview of Piraeus Port

Piraeus Port is located on the northeast bank of Saronikos Bay on the southeast coast of Greece, close to the southwest side of the Aegean Sea and adjacent to the Suez Canal. Located at the entrance and exit of the capital Athens, the port is the largest port in Greece and one of the largest ports in the Mediterranean. It is only 8 kilometers away from Athens, with electrified railways and expressways directly to all major cities [39] (see Fig.54 and see Fig.55). The main industries in Piraeus Port are shipbuilding, chemistry, machinery manufacturing, metallurgy, textile, etc. It is also an oil refining

center with an annual output of 2.5 million tons of petroleum products. Inland, the port extends to the Balkan region, while sea transportation from the port can reach to the Mediterranean Sea, the Black Sea, North Africa and other surrounding areas. In 2019, the port received 17.6 million passengers, making it the port with the largest passenger flow. In the same year, the container throughput also reached the highest among Mediterranean ports [41]. The Port of Piraeus has directly created 3,000 local jobs and indirectly added 10,000 jobs. Its output value of logistics has also grew from 400 million euros to 2.5 billion euros. According to the forecast of the Economic and Industrial Research Foundation, a Greek think tank, the Port of Piraeus will contribute about 0.8% of Greece's GDP growth in 2025, which would reduce public debt by 2.3% of the country's GDP.

Fig. 54 Piraeus Port

Fig. 55 Cargo transportation at Piraeus Port

(Picture from sohu.com)

In 2008, COSCO Shipping Group Co., Ltd. (hereinafter referred to as COSCO Shipping) signed a 35-year franchise agreement with Greece, after which the company officially took over the No. 2 and No. 3 container terminals of Piraeus port on October 1, 2010. In August 2016, COSCO marine acquired 67% of the equity of Piraeus Port, which is also the first time that a Chinese enterprise has taken over the whole port overseas. In 2020, the container throughput of Piraeus Port will be 5.44 million TEUs [41].

Greece lies at the intersection of the land Silk Road and the maritime Silk Road. Piraeus Port is the largest port in Greece and is regarded as the "southern gateway" of Europe. Through Piraeus Port, COSCO Shipping has opened a special freight train "China-Europe Land and Sea Express" from Piraeus Port to central and eastern Europe. After landing at Piraeus Port, sea freight can be transported by rail to Hungary, Austria, Czech Republic, Slovakia and other central European countries in only 3 to 4 days. Compared with traditional transit routes, the China-Europe Land and Sea Express starting from Piraeus Port can reduce the delivery time of the railway transportation by 5 to 10 days [42].

2.4.1.2 Green Development Measures and Achievements

(1) Creating New Routes to Reduce Carbon Emissions

As the logistics industry grows, more attention has been given to its impact on the environment and resources consumption. Piraeus port is one of the important ports in the construction of the maritime Silk Road and the shortest sea route from China to Europe (see Fig.56). The research shows that [43], the shortening of the route distance via Piraeus Port reduces the number of ships at the port under the same transportation demand, and lowers the annual carbon dioxide emissions. In addition, COSCO Shipping has reduced the unit fuel consumption by 35% and reduced the carbon dioxide emissions by adjusting the fleet structure, improving the ship operation capacity, optimizing the route design and lowering the speed (see Fig.57).

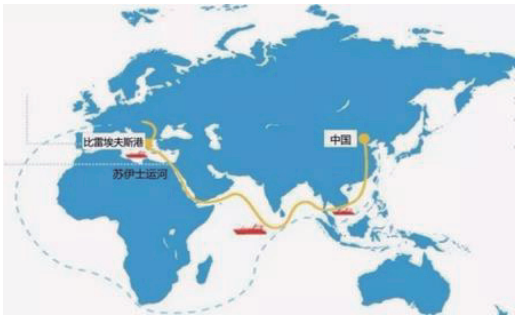

Fig. 56 Transport route map for Piraeus Port

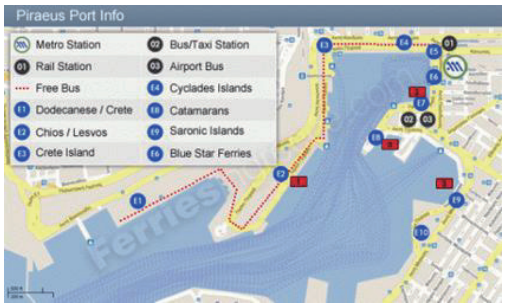

Fig. 57 Distribution at Piraeus Port

(Picture from sohu.com)

(2) Carrying out Pilot Studies on Environmental Monitoring

COSCO Shipping (Piraeus) Port Co., Ltd. worked with Piraeus municipal government and the Institute of Communication and Computer Systems of Athens National University of Technology to carry out pilot researches on environmental monitoring. The company also participated in the EU green C port project (see Fig.58). With the support of the green C port project, environmental and meteorological sensors and noise sensors were installed in Piraeus Port. The data of all sensors will be transmitted to the Green C Port Project's digital platform for analysis with results fed back to Piraeus Port with innovative solutions to help reduce the negative impact of port operations on the environment, lower the noise level, and improve air quality [44].

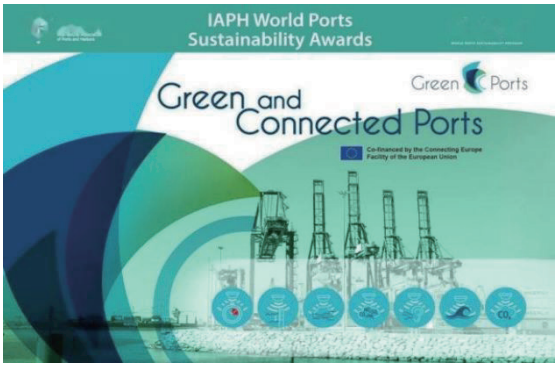

Fig. 58 EU Green C Port Project won the international award

(Picture from sohu.com)

(3) Promoting the Development of Port Bridge Crane Technology

In the various processes of container cargo transportation at the port, stowage, as one of the core links, has a direct impact on the operation efficiency of the automated terminal, the ships' time-in-port and the effective use of resources. After the Chinese company took over the operation of Piraeus Port, the number of boxes loaded and unloaded by each bridge crane of terminal 2 per hour increased from 15 TEU to 27 TEU. The increase in the utilization efficiency of equipment helped the port realize efficient and energy-saving growth and greatly reduced the operation costs. In addition, the bridge cranes on the west side of terminal 3 are the highest in the world at present, with a maximum lifting height of 54 meters and an extension of 72 meters. They can load and unload 26 rows of container ships (see Fig.59 and Fig.60). The improvement of technical capacity guarantees efficient operation of the container terminal at Piraeus Port [45]. With the general trend of global economic integration, the shipping volume of container cargo in various countries soared with an increasing volume of container fleets globally and a higher proportion of large ships, which brings greater challenges to the terminal. The inefficiency in handling port businesses and the long laytime led to traffic congestion at the gate and weighbridge, which lowered the efficiency of collection and distribution at the port. The improvement of bridge crane technology can effectively improve the utilization rate of resources, reduce the berthing time of ships,

and thus cut the consumption of resources and facilitate energy conservation for the green development of the port.

Fig. 59 Transport ship at Piraeus Port

Fig. 60 Cargo loading and unloading at Piraeus Port

(Picture from observer network)

2.4.2 Mombasa Port Project

2.4.2.1Project Background and Overview

Mombasa is the second largest city in Kenya and the capital of Coastal Province. It is located on the southeast coast near the Indian Ocean with a city center located on the island. The city is connected to the mainland by causeways and railway bridges. The Port of Mombasa, located on the island of Mombasa, is the largest port in Kenya and one of the largest ports in East Africa (see Fig.61). Most of the foreign trade materials of Kenya and Uganda and a part of the goods from Rwanda, Tanzania, eastern Zaire and southern Sudan are transshipped here [46]. As an important trading port in as early as 3,000 years ago, Mombasa has been closely related to the Maritime Silk Road. The implementation of the Belt and Road Initiative has brought new vitality to this ancient port.

In 2010, CRBC signed an agreement with Kenya Ports Authority to build the No. 19 berth with a length of 240 meters and a rear yard of 69,000 square meters in Mombasa Port. In August 2013, the No. 19 berth of Mombasa port was officially put in operation (see Fig.62). After the completion of the No. 19 berth, the container throughput of Mombasa Port is expected to increase by 25% from the original throughput of 22 million tons, and the daily storage capacity can be increased by about 4000 to 5000 TEU. As the first port project undertaken by a Chinese company in Kenya, berth No. 19 has improved its cargo handling capacity of Mombasa and consolidated Kenya's important status as the leader of economic development in the East African Community [47].

In February 2019, the Mombasa oil terminal project in Kenya undertaken by China Communications Construction Co., Ltd. (CCCC) was officially kicked off, including the construction of four new offshore berths and oil pipeline facilities, which allows the import and export of crude oil, heavy oil, gasoline, diesel, kerosene and liquefied petroleum gas to operate simultaneously. Mombasa oil terminal project was completed in early 2022 and is expected to be delivered and put into operation in August 2022. Upon completion, the project will become the first world-class modern oil and gas loading and unloading terminal in Kenya, which can simultaneously realize the import and export of crude oil, heavy oil, gasoline, diesel, kerosene and liquefied petroleum gas and reduce the fuel cost in Kenya, injecting vitality into the economic development of Kenya and even the whole East Africa.

Fig. 61 Aerial view of Mombasa port

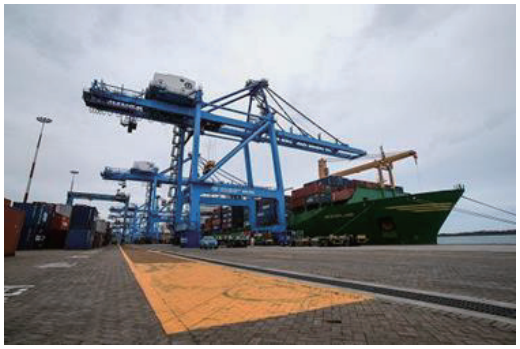

Fig. 62 No. 19 berth of Mombasa Port

(Picture from Xinhua News Agency)

2.4.2.2 Green Development Measures and Achievements

(1) Construction of Oil Terminal Project to Improve Fuel Treatment Efficiency

The Mombasa port oil terminal, built in 1963, is an important channel for the import and export of oil products in Kenya and surrounding countries, contributing greatly to the local economic development (see Fig.63 and Fig 64). Since the original capacity of the terminal can no longer meet the needs of Kenya's rapid economic development, the country began to prepare for the construction of a new oil terminal project in 2012. The Mombasa oil terminal project undertaken by Chinese enterprises can greatly improve the oil and gas transfer capacity of Mombasa port and reduce local fuel costs. At the same time, it will also bring a series of benefits such as shortening ship turnover time, ensuring supply safety and reducing transportation costs.

Fig. 63 Oil terminal of Mombasa Port

Fig. 64 Oil pipeline of oil terminal of Mombasa Port

(Picture from Xinhua News Agency)

(2) Mangrove Protection

According to the engineering design, Mombasa oil terminal project plans to build a pipeline processing plant under the sea. The south bank of Mombasa Island is blessed with a relatively high terrain, gentle mountain slope, no geological disasters such as landslides and mudslides, and no centralized blasting area and industrial seismic source nearby, which makes it the best site for the pipeline processing plant. However, Kenya is a famous tourist country in Africa with strict requirements for environmental protection. There is a mangrove planning area near the site of the pipeline processing plant. The mangrove can not only prevent wind and waves, consolidate the bank and protect the embankment, but also form a fixed biological community after flourishing, and thus plays an important role in maintaining ecological balance. Therefore, it is necessary to come up with an excellent plan for both engineering construction and environmental protection [48].

Under the concept of environmental protection, the project teams looked for a way to build a plant on the south bank while minimizing the impact on the environment. After a discussion with the local port authority and the environmental bureau, the project team decided to set aside a planting area for 45,000 mangrove seedlings between the processing plant site and the mangrove planning area, so as to compensate the damaged mangroves and reduce the impact on the environment (see Fig.65 and Fig.66). Though the mangrove planning area does not meet the requirement on transplant conditions, the beach in the designated planting area is very suitable for rebuilding a mangrove.

Fig. 65 Mangrove planting site

Fig. 66 Mangrove growing on the site

(Picture from Official Website of CCCC)

Whether this mangrove forest can take shape or not depends on the cultivation of seedlings. Therefore, the project department specially entrusts the local mangrove protection community to cultivate mangrove seedlings. Every step in raising seedling, from the allocation of nutrient soil, to sowing, seedling refining and disease and pest control, requires great care. In February 2020, mangrove seedlings successfully passed the acceptance of the local related departments, and the planting work was officially started. The project team frequently visited the planting area to make sure that the planting density and the progress of planting activities are proper and can guarantee the survival rate of seedlings. After more than one month, all of the 45,000 mangrove seedlings were planted.

2.4.3 Summary

According to the statistics of the United Nations Conference on Trade and Development, 80% of the global trade in goods is realized by sea [49]. The diversified opportunities brought about by the BRI involve a large number of transnational transportation. As an important pivot and carrier of the 21st century Maritime Silk Road, ports carry important functions of transnational transportation. In recent years, China has participated in the construction of a large number of international ports in different ways in the BRI countries. As a result, the degree of maritime connectivity has been continuously strengthened, the port cooperation has been deepened, and the infrastructure construction and operation

capacity of relevant ports have been continuously improved, contributing greatly to the economic development of various countries and the smooth flow of global trade.

There is a natural connection between port project construction and shipping industry. The volume of greenhouse gas emissions generated by global ocean transportation is equivalent to about 1 billion tons of carbon dioxide each year, accounting for about 3% of the global carbon dioxide emissions caused by human activities. If no emission control measures are taken, it is expected that greenhouse gas emissions will more than double in the next few years, which will bring great challenges to achieving the goal of the Paris Agreement. Port activities, such as berthing (mooring), may exert an impact with oil leakage, air pollution, noise and light pollution. Ship traffic is prone to generate underwater noise pollution. Ships may harm marine giant animals, and ships may release ballast water containing invasive aquatic species during their movement. The total amount of greenhouse gas emissions from ships is relatively large, and the large-scale marine development, marine transportation and coastal storage of dangerous chemicals such as oil products also increase the risk of marine pollution.

In order to achieve green and low-carbon development, many ports along the BRI routes are expediting the construction of green ports and promoting the synergy between port construction and city planning and improving the cleanliness of ports. Piraeus Port reduces energy consumption by adjusting the fleet structure and creating new routes. It also cuts carbon emissions by optimizing resource utilization through improved bridge crane technology. At the same time, pilot researches on environmental monitoring are carried out to monitor the impact of port operation on the environment and offer timely solutions. On the one hand, Mombasa port improves the fuel treatment efficiency by undertaking the oil terminal project; on the other hand, it plans to rebuild a mangrove forest in a new planting area to make up for mangroves transplanted due to the project construction. The green development measures have brought good environmental benefits in the process of port project construction and operation, and promoted the development of green ports. In addition, there are many other green practices in the port projects under the framework of BRI: Colombo Port of Sri Lanka completed the “oil to electricity”

transformation of 40 gantry cranes and 40 container yards in November 2017, making it the first green terminal in Sri Lanka and the largest one in South Asia. “Oil to electricity” transformations can reduce the cost of the enterprise by about US $1.45 million per year and lowered the diesel consumption of the gantry crane and the total direct carbon dioxide emissions by 95%, so as to provide a healthier working environment for the on-site operators by reducing noise pollution and air pollution [50].

Chapter III Green Mobility

3.1 Development of Electric Vehicles in Hungary

Europe is the birthplace of electric vehicles. As early as the mid-19th century, Hungarian Engineer Jedlik Ányos completed the electric actuator in his laboratory and then invented the world's first electric vehicle. The automobile industry is now an important pillar of the Hungarian economy, accounting for 28.5% of its total manufacturing industry. In recent years, the automobile industry, in search of industrial upgrade, has been stepping up its efforts to develop new energy vehicles. Hungary's share of electric vehicles in 2019 was 1.9%, lower than the European average, but the highest among Eastern European countries. In 2021, 4311 new electric vehicles were offered for sale in Hungary, with a sales increase of 41.53%.

3.1.1 Policy Support for Electric Vehicle Industry

3.1.1.1 Electric Vehicles and Charging Infrastructure

In 2015, Mihály Varga , then Minister of National Economy of Hungarian, said that Hungary had allocated 25% of its carbon quota income to supporting the construction of electric vehicle infrastructure. According to the plan, 150 charging stations would be set up in Budapest first, followed by charging facilities along expressways and in large cities, allowing easy access by EVs throughout the country. In November 2018, Hungary's largest electric vehicle charging station was opened in Sormás, western Hungary. MVM, the Hungarian national utility company, built this charging station near the M7 expressway in Sormás and planned to open more charging stations throughout the country. The facility costs tens of millions of HUF and can charge nine cars at the same time [51]. As of February 2019, Hungary had 100 public charging stations in operation, of which 10% were fast chargers (see Fig.67). The goal of the MVM is to build as many chargers as possible so that charging stations can be found every 80-100Km. According to data of the Hungarian Energy and Public Utility Regulatory

Authority (HEPURA), in 2020, drivers used a total of 7.1GWh of energy in public electric charging stations, and the number of charging reached 708,579 times [52].

Figure 67 A Public Charging Station in Central Budapest

(Picture from ce.cn[53])

In 2016, the Hungarian government set the development goal for the electric vehicle industry, proposing that the number of electric vehicles be increased from 600 to 50,000 by 2020, and requiring that charging piles be installed in large parking lots where conditions met. Through announcing such ambitious goals, Hungary aims to become a regional leader in the development of EVs. At the same time, the preferential policy for purchasing electric vehicles was introduced. When purchasing BEVs, applicants can get up to 21% discount , or 1.5 million HUF. The policy is not only for individuals, but also for enterprises, non-governmental organizations, local governments, public institutions and financial institutions. According to the plan, the Hungarian government will allocate 3 billion HUF to promote the rapid development of electric vehicles nationwide. At the same time, in order to encourage residents to buy electric vehicles, the Hungarian government has introduced preferential policies such as free parking, free charging and car tax exemption in designated areas. In terms of official vehicles, Hungary has purchased more than 200 electric vehicles for local governments and state-owned

enterprises, with a value of about 2 billion HUF. In addition, the purchase and operation of electric taxis will be encouraged, and the number of electric buses will be further expanded.

In 2020, the Hungarian Association for Innovation announced that those purchasing electric vehicles with a price of no more than 11 million HUF could receive a government subsidy of 2.5 million HUF. The purpose of the subsidy policy is not to encourage people to buy long-distance vehicles with large battery packs, but to encourage the purchase of small electric vehicles with a range of 200-300Km that are suitable for urban and suburban use. In addition, the government also supports the purchase of electric motors and scooters. Electric vehicles used as taxis can also receive higher subsidies than before. The policy would continue until June 1st, 2022, with a subsidy budget of HUF 5 billion.

3.1.1.2 Hungary Green Bus Plan

In 2019, Hungary planned to introduce green electric buses into its public transport system. It is expected that 7,500 buses would be replaced by more environmentally-friendly electric vehicles in the next ten years, or one in every six buses (see Fig.68). According to the decision of the Hungarian government, from 2022, cities with a population of more than 25,000 can only operate non-emission buses, and the government will provide financial support for their procurement. It is estimated that the modernization of public transport in Hungary will require about 169 million HUF, of which 20% will be paid by government funds, while the rest will be covered by the Parliament and private companies, including companies such as Ikarus and BYD [54].

Figure 68 Electric Bus in Hungary

(Photo Source: Wikipedia,)

In 2020, the Hungarian Parliament passed the Climate Protection Act. The government announced an action plan on climate and nature protection, which includes promoting green transportation and supporting the purchase and use of low-emission or zero-emission electric buses. The government also launched the green bus pilot program.. It is expected that half of the Hungarian buses will be replaced with a subsidy of 36 billion HUF for the purchase of electric buses within 10 years, 20% higher than the previous planned budget. In September 2020, the first demonstration project was launched in Debrecen. In November 2020, the Hungarian government purchased 60 new Mercedes Benz Conecto G articulated buses. The green bus plan also aims to promote domestic electric bus manufacturing, with the goal of at least 60% of electric buses being manufactured in Hungary., To this end, Hungary will also establish a bus manufacturing industrial park.. By the end of July 2020, 8 domestic and foreign manufacturers have submitted applications [55].

3.1.2 Build an Electric Vehicle Manufacturing Center

Attracted by the advantages of Hungary in geographical location, talents and technology, the world's automobile giants have been building production lines in Hungary in the past few years. In June 2018, Mercedes Benz announced the launch of the Full-Flex conceptual intelligent factory plan in Kecskemet, Hungary, with an initial investment of 1 billion EUR. The highly flexible production line is capable of producing a variety of vehicle frames from compact models to rear wheel drive cars and electric vehicles. In December 2020, officials of the Hungarian Ministry of Foreign Affairs and Trade said that Mercedes Benz would invest 50 billion EUR to produce electric vehicles in the city of Kecskemet [56]. In August 2018, BMW announced the building of a new plant near Debrecen with an investment of 1 billion EUR to produce fuel and electric vehicles [57]. Since 2018, Audi has been producing electric motors in Hungary, which has become a major production base of the company. In June 2022, Audi declared that it would spend 320 million US dollars to further expand its Hungarian factory with an extra investment of 22 million US dollars from the government. Hungary also provides the largest investment subsidy and convenience for the production of batteries in history. SK Innovation of Korea

announced in 2018, 2019 and 2021 that it would invest in the construction of three electric vehicle battery plants in Hungary. Hungary is rapidly becoming an important production center of electric vehicles.

3.1.3 Introduction of Chinese Electric Vehicle Manufacturers

3.1.3.1 BYD Set Up Factory in Hungary

In recent years, Chinese enterprises have continuously strengthened investment cooperation with Hungary in the field of new energy vehicles. In 2016, BYD began to build its first European factory, and Hungary became the first new energy electric vehicle production base established by BYD in Europe. In April 2017, the first electric bus factory built by BYD in Europe was put into operation in Hungary, with a total investment of 20 million EUR. In September 2017, the first eBus produced by BYD in Hungary rolled off the production line.. In 2019, the pure electric BYD eBuses produced by BYD's Hungarian factory were put into use in the Hungarian city of Salgótarjan, which is the first electric bus in this Hungarian border city. In July 2020, BYD successfully delivered 10 12-meter eBuses to the Hungarian public transport operator Tüke Busz Zrt. These vehicles were manufactured in BYD's local bus factory in Hungary and would be put into use in the southwestern city of Pécs, marking the official launch of the first batch of battery electric buses in the history of the city (see Fig. 69 and Fig.70).

Figure 69 BYD's eBus Fleet Delivered to Pécs, Hungary

Figure 70 BYD 12-meter eBus

(Picture from: VHUI.com)

The latest two-door, low-floor BYD vehicles delivers a 300 km single-charge range. The. 10 buses, once put into use, were expected to have an annual total mileage of 900,000 km, accounting for 10% of the total mileage of the operator. At the same time, BYD also customized charging facilities for this fleet and provided a package of integrated solutions for electrification [60]. Since 2016, BYD has invested more than 30 million EUR in Hungary, and the order volume has been growing steadily. BYD has become an important player in the European electric bus market.

3.1.3.2 CRRC Electric "San Bus King"

In 2017, CRRC Urban Transportation Co., Ltd., a subsidiary of CRRC, established a joint venture with the time-honored local brand automobile enterprise Ikarus, namely, Electribus Europe Zrt. With the help of the experienced local industrial workers and mature market service system, it started to produce intelligent and green electric buses for Europe. In December 2018, the first jointly produced 12-meter pure electric e-bus prototype "San Bus King" was unveiled in the city of Székesfehérvár, Hungary (see Fig.71). CRRC Electric offered entire design, body manufacturing and core system, while Ikarus was responsible for electrical appliance assembly and interior decoration. The Hungarian city of Székesfehérvár, together with four partners, including Electribus Europe Zrt and CRRC Electric, signed a cooperation agreement on the development of green transportation in the city. The joint efforts of the municipal government of Székesfehérvár, Ikarus and CRRC have ushered in a new era for the public transportation market in Hungary featured by new energy public transport and the electrification of urban transit system, adding new highlights to the practical economic and trade cooperation between China and Hungary.

Figure 71 Pure Electric eBus "San Bus King" Jointly Produced by China and Hungary

(Picture from: Sohu.com [59])

In October 2019, "San Bus King 2.0" was launched (see Fig.72). With a stainless steel body, "San Bus King 2.0" reduced its weight by 400 kg, saving power consumption of about 0.8-1Kwh per 100 km. The new model, which boasted state-of-the-art "Spider Man" battery management system and "Iron Man" driving safety system, enabled a huge improvement in comprehensive performance from the original version.

Figure 72 "San Bus King 2.0"

(Picture from: workercn.cn [60])

The Hungarian government has given great support to zero-emission transport. In 2020, 3,000 BEVs and 3,000 plug-in hybrid vehicles were sold. A total of 6,042 EVs were sold,

exceeding that of the Czech Republic (5,234), Romania (2,837), Greece (2,135) and Slovakia (1,484), and also exceeding that of Poland (8,099) in terms of per capita. Hungary performed better in the field of hybrid vehicles. The number of new cars sold increased by 2.5 times in one year, from 12,000 to 38,000, obtaining the fastest growth in Europe. It not only exceeded Eastern European countries, but also led Austria, Belgium, Finland, Ireland and Sweden. With the automobile market restructuring, in 2020, one of every four new cars sold in Hungary was HEV, and one of every 20 was electric rechargeable vehicle [61].

3.2 Development of Green Transport in Istanbul, Türkiye

3.2.1 Development of Electric Vehicles

According to a report of SHURA, an energy transformation think tank headquartered in Istanbul, there were about 1,500 electric vehicles and more than 1,000 charging stations in Türkiye in 2019. According to the report, by 2030, the number of EVs and EV charging stations will increase to 2.5 million and 1 million respectively. According to SHURA Energy Transition Center, the area covering the Istanbul-Ankara Expressway will be the first to see the booming of the EV market.

Learning from China's experience in promoting new energy, the government of Türkiye will also greatly improve the penetration rate of public charging stations. According to government report, the demand for electric vehicles in Türkiye will increase by about 200,000 in the next three years. At present, hoping to seize the opportunity, global automobile giants have started to rapidly introduce their products to the market.

3.2.1.1 Independent Research and Development of Electric Vehicles

In December 2019, President Recep Tayyip Erdogan of Türkiye personally unveiled a series of prototype electric vehicles developed and manufactured by Türkiye, a step closer to realizing his enduring dream of launching a Turkish national automobile brand.. On the same day, Erdogan introduced to the world the Türkiye Automobile Group (TOGG), an EV

brand jointly developed by several Turkish companies, and its SUV and sedan models at a ceremony in Gebze, an important industrial port in the northwest of the country. After the Ceremony, Erdogan drove one of the SUVs through a suspension bridge across the Izmit Bay. It is reported that, in addition to these two models, TOGG planned to launch five more models in the future with an expected single-charge range of 300 miles (about 480Km).

As a new automobile enterprise supported by the government with an investment of US $3.7 billion, TOGG's electric vehicle project in Türkiye is located in Bursa city in the south of the capital Istanbul. After being put into operation in July 2021, and the first electric car was released at the end of 2022, with a production capacity of 100,000 vehicles per year. In the 15 years after 2022, the project is expected to contribute 38.2 billion pounds (about RMB 349.5 billion) to Türkiye's economy [62]. After being sold in the Turkish domestic market, these cars will first enter the German market in about a year and a half, and then be supplied to the entire European market. TOGG also partnered with Chinese battery company Farasis Energy to produce batteries.

In June 2018, five industrial giants - Anadolu Group, BMC, KK Group, Turkcell and Zorlu Holding, together with the Union of Chambers and Commodity Exchanges of Türkiye (TOBB) jointly established TOGG. According to its plan, The company, owning all intellectual and industrial rights, will launch five different models - sports utility vehicle (SUV), sedan, C-type hatchback, B-type SUV and B-type MPV by 2030. At present, major international automobile manufacturers, including Fiat Chrysler, Ford, Hyundai, Renault and Toyota, have production or assembly lines in Türkiye.

In August 2021, the CEO of TOGG said that the first BEV model in Türkiye would be rolled off the production line by the end of 2022, making the company the first non-traditional inborn electric SUV manufacturer in Europe. After being sold in the domestic market, these vehicles would first enter the German market in about one and a half years, and then supplied

to the entire European market. TOGG also cooperates with Chinese battery company Farasis Energy to produce batteries.

3.2.1.2 Electric Express Tricycles

Turkish Post uses electric vehicles for parcel delivery in some areas of Istanbul. The last mile of express delivery with electric vehicles (see Fig.73) results in zero emission and zero pollution. For Princes' Islands, where four-wheel carriages and bicycles are the only means of transportation, the move not only improves the efficiency of last-mile delivery, but also bears no impact on the environment.

Figure 73 Turkish Post Uses Electric Express Tricycles

(Picture from: yescaidingyue.com)

Turkish Post is the first enterprise in Türkiye to use electric vehicles for parcel delivery. Since the beginning of 2021, Turkish Post has put electric vehicles into use in four islands in Istanbul province.

3.2.2 Building Public Transport Network

As an international metropolis spanning the Eurasian continent, Istanbul is the transportation hub of the whole country and even the world. The highly developed public transportation system provides a variety of choices: ground transportation, underground transportation, rail transportation, ships and ferries are all available.

At present, Istanbul has four main subway lines (see Fig.74). M1 and M2, covering Ataturk International Airport and major scenic spots in the European regions, are the most frequently used by tourists. M3 is far from major scenic spots, and M4 is located in the Asian regions [63].

Figure 74 Istanbul Metro

(Picture from: shjzhou.com)

Ground and Underground railways together form a very convenient rail transit system in Istanbul. At present, there are four light rail lines in the city, namely T1, T2, T3 and T4. In addition, there are retro light rail on the famous İstiklal Caddesi street (see Fig.75).

Figure 75 Istanbul Light Rail

(Picture from: shjzhou.com)

The bus lines spanning across the whole city (see Fig.76) are the most frequently chosen transport for local people.

Figure 76 Key Public Transport Corridors in Istanbul

(Picture from: Report from Gehl Architects [64])

As a city crossing the Eurasian continent, ferry transport plays an important role in Istanbul. Thousands of people shuttle between Europe and Asia every day. For tourists, it is almost inevitable to cross the Bosporus Strait by sea (see Fig.77). In addition to crossing the Eurasian continent, you can also travel to the many small islands of the Princes' Islands by ferry.

Figure 77 Ferry in Istanbul

(photo source: Jiuzhou, Shanghai)

Thanks to its unique terrain and urban structure, Istanbul has many fascinating street views, providing pedestrians with a variety of walking experiences (see Fig.78). Trams are common in Istanbul, and their operation isolates the main street from the east, creating a quiet atmosphere in the area. Pedestrians are seen everywhere in Istanbul (see Fig.79), adding vitality to the streets and demonstrating healthy and sustainable ways of life.

Figure 78 Fascinating Walking Routes

Figure 79 Istanbul by Foot

(Picture from: Report from Gehl Architects)

3.2.3 Building Green Ports

In June 2017, the first "Green Port" Certificate Issuing Ceremony was held in the capital city of Ankara by the Turkish Ministry of Transport, Maritime and Communications. Kumport, acquired and operated by COSCOPAC, was awarded the "Green Port" certificate for its outstanding contribution to the development of green ports (see Fig.80).

Figure 80 "Green Port" certificate issued by the Turkish Minister of Transport, Maritime and Communications for Kumport

(Picture from: Maritime China [66])

Since being acquired by COSCO, China Merchants and CIC in 2015, Kumport has been making continuous progress in its business performance, and has become an important logistics hub along the "Belt and Road" (see Fig.81). The success of the port cannot be achieved without green management, intelligent operation and maintenance, alignment with international standards, and other advanced concepts and methods.

Figure 81 Scene of Kumport

(Picture from: cnr.cn)

The Port of Kumport is one of the first enterprises in Türkiye to obtain the “Green Port” certificate, and is also the third container terminal in Türkiye to obtain this certificate. Adhering to the philosophy of green development, Port of Kumport passed the certificate renewal review of ISO 14001 environmental management system and OHSAS 18001 occupational health and safety management system in 2016, further accelerating the progress of the development of “Green Port”.

Security is an important part of building a green port. 341 cameras are installed at the port to comprehensively monitor the safety of personnel and goods. 60 security workers work in three shifts round the clock. The definition of safety accidents at the wharf is very strict. For example, stumbling on a container at the wharf, scratching the hand with a hammer should all be reported as an accident. No fraud or perfunctory behavior is allowed. Under strict safety supervision, there has been no serious casualty accident at the port since the acquisition [66].

Automatic and intelligent management is another effective way to improve safety. A self-developed system application can be linked with the terminal central operating system to easily obtain the data and historic records on the status, operation efficiency, loading capacity and resource allocation of docked ships. The realization of unmanned automated port lies in the near future.

Environmental protection key element of a green port.. Kumport has achieved remarkable progress in low-carbon development, environmental protection, energy conservation and emission reduction. It is reported that the fuel emission, carbon emission, water resource use and mechanical equipment energy conservation standards of the terminal meet the requirements of the “Green Port” rating evaluation system. In November 2017, Kumport was awarded the 5-star Excellence Award by European Quality Management Foundation (EFQM), which is the highest level of the Award and also another affirmation of the port’s quality management performance.

3.3 Building an Integrated Urban Transport System in Singapore

3.3.1 Multimodal Transport

In order to achieve intensive development of resources and green urban transport development, Singapore has established an integrated bus system. Singapore's bus system is closely integrated with the development of urban residential, commercial and office zones. The bus hubs integrate urban land development and become key points of multi-functional urban living development. In most new towns, the bus terminal stations and the communities are combined for integrated residential development. Most residents live within a 5-minute walking distance from bus stops and can easily get to hub stations, making it convenient and fast to get around. Many hub stations also combine commerce, office and leisure functions, forming a multi-functional urban complex featuring integrated development. This mode is connected with various modes of transportation and has achieved good economic, social and environmental benefits [67] (see Fig.82).

Figure 82 Transfer between Bus and Subway

(Picture from: news.cctv.com)

Singapore implements multimodal transport in its transportation system. This trip mode chain is a key measure to achieve energy conservation and emission reduction, as well as reduce traffic pollution and improve transport efficiency. In terms of integration with

residential, office, commercial and living facilities, bus hubs have formed a comprehensive and well-organized green transportation system (see Fig.83).

Intensive hub construction can avoid resource overlap among urban traffic corridors. Integrating green transportation can reduce travel cost and improve service quality, which is an important factor for realizing the sustainable development of urban transportation.

Figure 83 pedestrian overpass outside the bus terminal

(Picture from: people.com.cn)

3.3.2 Urban Green Intelligent Traffic Management

In 1998, the Singapore government started to use the Electronic Road Pricing (ERP) System to solve the problem of traffic congestion and parking for jammed roadways. Statistics show that there are nearly 100 ERP systems in different regions and road sections in Singapore. On the electronic screen, the charging price changes in real time according to time periods, vehicle types and road situations (see Fig.84). The government of Singapore has announced that by the second half of 2023, the country will enter the second generation of all-satellite era. That charging system also charge by mileage, or by real-time traffic conditions and average urban traffic conditions. Through unified management of the government, the problem of urban congestion has been solved to a large extent, contributing greatly to the realization of urban green intelligent traffic management [68].

Figure 84 Intelligent Electronic Road Pricing (ERP) System

(Picture from: news.cn)

The road network monitoring system adopted in Singapore has a control center which continuously monitors the traffic network of the whole island 24 hours a day, and transmits the obtained data to various electronic information distribution systems in real time to maintain smooth and efficient road traffic. This system can not only provide real-time traffic data for the Transport Department to tackle congestion, but can also feedback the road network information to drivers to help them choose the best route and improve efficiency.

By building a series of intelligent transportation systems, Singapore has basically realized the combination of travelers, travel modes and travel paths in the road network as a whole, helping the government obtain timely traffic data and provide efficient and convenient traffic services, which is of great significance to the realization of green intelligent transportation management in the whole city.

3.3.3 Advocate Public Transport

In order to protect the urban environment and combat congestion, the government of Singapore has adopted various measures to control the quantity of vehicles, mainly by setting high tariffs on car purchase (20%), additional registration fees (100%), Certificate of Entitlement (COE) fees, road taxes and so on. For example, all new vehicles must purchase a COE and get a limited-area license with a validity of 10 years to control the number of vehicles. In addition, the government adopts the vehicle quota system to conduct

public electronic bidding, and the changes of COE fees reflect the status of supply and demand in the market. Singapore's government has reduced the number of cars with these measures to ensure air quality, and realize the development of urban green transportation.

In addition, the government has also issued relevant policies to support public transport development and encourage people to choose mass transit. The government bears the cost of public transport infrastructure construction, and strives to reduce the waiting time of passengers and improve the quality of bus services. Moreover, the regulation of bus fares is strengthened. Passengers are charged based on the distance they travel, getting more flexibility and convenience to choose the best route.

Figure 85 New Urban Public Transport in Singapore

(Picture from: cscec.com)

With the goal of achieving 75% of the public transport share by 2030, Singapore is constantly improving the public transport service network, ensuring that buses and subways are better choices and encouraging more people to take mass transit, building transport hubs for air-conditioned buses effectively and moving towards the actual realization of intelligent green transportation in the city [60] (see Fig.85).

3.3.4 Transit-oriented Development

In order to realize green urbanism and build cities with sustainable transport, firstly, Singapore forms traffic corridors with its mass transits and offers high-quality transit services, building the framework of the city's development. Traffic sites are in compliance with the concept of Transit Oriented Development (TOD), and have formed high-density and multifunctional station spaces (see Fig.86). Secondly, Singapore's new towns have

successfully divert the population in the urban center. The hierarchical urban structure is connected by public transport networks, featuring “decentralized but compact”. That form is conducive to the development of small-scale energy, water and waste recycling systems in various communities and drives the ecological development of the whole city [70].

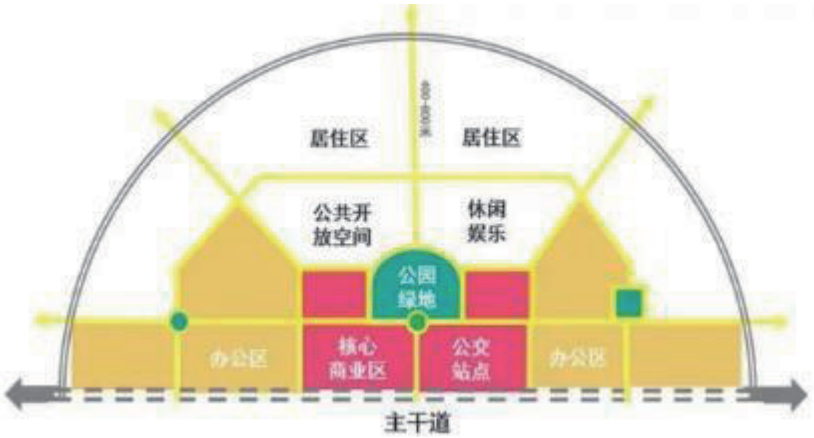

Figure 86 Practice of TOD Mode in Singapore

(Picture from: baike.baidu.com)

In addition, Singapore’s green TOD practice is different from that in European cities. With an area of 700 square kilometers, Singapore gives the highest priority to the development of mass public transit. The woodlands and water sources in the central area are protected as natural reserves, achieving harmony between the man-made and the natural ecological environment.

As a representative of Asia’s high-density cities, Singapore has managed to balance the efficiency of city functioning, population pressure and the indigenous practice of green urbanism. The green TOD of the city has the characteristics of compactness and hierarchy. While exploring new modes, Singapore has connected 23 new towns through the public transport network, presenting the feature of being “decentralized but compact”. For public transport communities with high density and ecological characteristics, they make it convenient for all regions to develop energy, water and waste recycling systems, which drives the sustainable and circular development of the whole city. Besides, the abundant open public spaces and three-dimensional greening brought by urban development further

promote the green development of the ecological environment, thus bridging the gap between the social environment and the natural ecosystem and making the city more livable. By practicing the green TOD mode, Singapore has achieved compact and ecological urban development, released the green effects of TOD, and made low-carbon commuting such as walking and cycling people's best choice. Through the construction of public places, more abundant public spaces and green corridors will be created for TOD to ensure that the city can realize advanced and improved intelligent green transportation.

3.4 Sustainable Transportation Development in Santiago, Chile

3.4.1 Development of Electric Vehicles

3.4.1.1 Highway Charging Plan

In recent years, the Chilean government has introduced a series of measures to combat air pollution, and promoting electric vehicles is one of them. In 2016, Chile developed a national strategy for electric vehicles, aiming to achieve the target of 40% of private electric vehicles by 2050. It is expected that public, private and commercial electric vehicles in the country will amount to 5 million by then, and the annual carbon emissions will be reduced by 11 million tons. On that basis, Chile proposed the “highway charging plan”.

In July 2021, Chile added a charging facility at the new Angostura toll station between the capital Santiago and Talca, which is the 5th charging point established along the No.5 Highway connecting the two cities. The charging pile features complete smart grid integration, power adaptation, mobile connectivity, remote control and maintenance, and compatibility with the main DC charging standards currently on the market. It can charge two vehicles at the same time in a minimum of 35 minutes. Chile’s “highway charging plan” is the most ambitious electric vehicle infrastructure project in Latin America, with 1,200 charging piles along a 4,000 km-long arterial road which runs from Arica, Chile's northernmost seaport, to Punta Arenas, Chile's southernmost city. There are two other

shorter “charging highways” located in the south-central region and along the southern border.

The “highway charging plan” will be able to meet more than 50% of the demand for vehicle charging facilities, and ensure that every 60Km along the road has at least one charging pile [71].

3.4.1.2 Build Electric Bus Corridors

Chile aims to build a 100% electric bus fleet by 2040. To that end, the Ministry of Transport of Chile proposed the “Red Mobility” standard at the end of 2018, aiming to develop clean energy buses and accelerate the process of electrification of urban public transport. Echoing the “Red Mobility” is the “Red Standard” in the country’s public transport system, which requires that the vehicle should be fully electric or meet the emission standards of EURO 6, and be equipped with air conditioner, Wi-Fi and USB charger [72].

In December 2018, Chile introduced 100 BYD battery electric buses into the municipal public transport system and established the largest battery electric bus fleet in the country at that time, taking the lead in promoting public transport electrification in Chile. All battery electric buses delivered to Chile by BYD meet the “Red Standard”. In October 2019, Gracia Avenue in Santiago officially became the first “electric bus corridor” in Latin America, which is for electric buses only. The BYD battery electric buses purchased by Chile from China operate on this avenue as scheduled, including 183 BYD electric buses that arrived in Chile in the second half of 2019 and were put into use for the first time (see Fig.87 and Fig.88). This electric bus corridor features bus stops with online information system, LED lighting, wireless Internet access, etc., bringing convenience to residents along the route[73].

In June 2020, BYD delivered another 150 battery electric buses to Santiago and put them into operation. By 2020, the battery electric buses delivered by BYD to Chile accounted for 65% of the country's bus market. According to local media, compared with traditional diesel buses, the noise of the electric buses in operation in Santiago is 25% to 70% lower, cut

operating costs by 76%, save maintenance costs by 25%, and can reduce carbon dioxide emissions by about 2.5 tons annually[74].

Fig.87 BYD Electric Buses on the Streets of Santiago

(Picture from: jrj.com)

Fig. 88 Passengers Boarding an Electric Bus

(Picture from: Bloomberg)

In May 2022, 70 new Chinese Foton Ouhui battery electric buses were delivered to the southern area in Santiago Metropolitan Region, and became part of the "Electric Corridor" in Santa Rosa Avenue.. Santiago Metropolitan Region is the most populous and densely populated area in Chile, and Santa Rosa Avenue in the southern area is one of the most important highways in Santiago, the second longest in Chile. As of May 2022, As of May 2022, the Metropolitan Region has had more than 800 electric buses in operation, including over 300 Ouhui battery electric vehicles, and it has become one of the largest battery electric bus fleets in the entire Latin American region. Featuring zero emission, zero pollution, and noise reduction, each Ouhui electric bus can carry 90 passengers, benefiting more than 55,000 residents in three regions, La Pintana, San Joaquin and Punte Alto. The operation of Ouhui electric buses has also driven the construction of charging facilities along the route. With the construction of two new charging stations on the main road of Santa Rosa, there will be 15 charging stations and more than 200 charging piles in Santiago Metropolitan Region in 2022. Santiago is becoming the benchmark and leading city of Chile in terms of transport electrification, effectively tackling the problem of carbon pollution caused by conventional cars and bringing tangible benefits to all residents along the route with green transport[75]. As residents support actions to improve air quality and recognize the benefits of an electrified transportation system, the city has seen a 6.5% reduction in fare evasion since the introduction of electric buses.

3.4.2 Encourage Cycling

In the early days of Santiago, there were few dedicated bicycle paths. In 2007, a program was proposed to build 690Km bicycle lanes throughout the city and rural areas. The plan has already shown results in some urban areas, where bicycles have been integrated into the local transportation system. For example, the public bicycle system has been established in Providencia since 2009, with the number of bicycles growing from 1,000 to more than 4,000 in 2017. As of 2018, Santiago, an average of 510,569 rides per day were recorded in

Santiago, which is the second highest in Latin America (see Fig.89), after Bogota, the capital of Colombia. There are altogether 2,513Km bicycle lanes in Latin America, of which Santiago has 300Km, accounting for more than 10%. However, back in 2003, Santiago had only 20 Km of bicycle lanes in total[78].

Figure 89 Citizens Riding Bicycles

(Picture from: *BRI Green Development Case Study Report (2020)*, BRIGC)

In order to encourage cycling, Santiago has also introduced high-quality bikeway design standards to reallocate road space and create more room for cyclists. This initiative has brought a very significant change to the city and its residents: the number of bicycle trips has increased significantly, from less than 150 person-times/day to more than 5,000 person-times/day. The bicycle boom has driven the development of bike-sharing. In 2015, there were only 150 shared bicycles in Santiago, which increased to 3,890 in 2017 [76]. By 2019, the number of shared bicycles and electronic scooters on the streets of Santiago reached 12,425, and the main operating companies included Mobike (see Fig.90, 7,000 bicycles), Bike Santiago (3,500 bicycles), Scoot (800 scooters and 125 bicycles) and Movo (500 Scooters)[77]. In addition, the city also promoted BMov Trici in historical and cultural centers and scenic spots, which is operated by a private company and free of charge. The goal was to encourage tourists to choose bicycles when visiting the city. The city also piloted the program of bicycle games in kindergartens to expose children to bicycles at an early age, and introduced traffic education in the primary school curriculum to regulate the kids' cycling behavior from an early age. Santiago has designed enough walking and cycling

spaces in the city center and improved the public transport system, which has effectively reduced traffic congestion and improved the quality of life of local residents. More and more Santiago residents are choosing cycling and walking as their means of travel.

At present, San Diego is further promoting electric bicycles. In September 2021, Bird, a micro-mobility company, partnered with San Diego State University and launched electric bicycles and Bird's second and third generation scooters to cover the 280 acre campus. The pedal-assist electric bike has a top speed of 15.5 miles per hour and can travel 56 miles on a single charge. It also comes with geofence technology that can automatically limit the speed of bicycles in certain areas.

Through sustainable traffic transformation, the traffic congestion in Santiago has been greatly improved, creating a comfortable, convenient, nature-friendly and people-oriented traffic system that promotes people to practice a green lifestyle, reduces air pollution caused by ground traffic, and improves the quality of life of residents. In 2017, Santiago won the International Sustainable Transportation Award for its rational public space design, well-developed cycling lanes and sidewalks, and successful promotion of public transportation.

Fig.90 Mobike in Santiago, Chile

(Picture from: cankaoxiaoxi.com.cn [78])

3.4.3 Re-development of Pedestrian-friendly Streets

Pedestrian friendliness is a critical step for cities to take in promoting sustainable transportation. Santiago is actively promoting pedestrian-first street upgrade. CalleAillavilú, a market in downtown Santiago, has been transformed from an abandoned, congested and unattended parking lot into a walkable oasis of recreation. The streets have been re-paved, the street lighting system is improved, new trees are planted, and most importantly, cars are no longer allowed to be parked there. No motor vehicles are allowed to park or pass through the area except for the delivery of goods. Calle Placer, the busiest and most popular pedestrian street in downtown Santiago, is adjacent to the CalleAillavilú market and has a high flow of visitors on weekends. After the renovation, Calle Placer is completely closed to traffic during the weekends. In addition, the municipal government invested $2.2 million in sidewalk, lighting and sanitation improvements to make this street more pedestrian friendly.

Fig. 91 Downtown Santiago, vehicles are not allowed to pass through after renovation and both sides of the street are decorated.

(Picture from: *BRI Green Development Case Study Report (2020)*, BRIGC)

Fig.92 Downtown Santiago, a street was changed from three lanes to single lane, widening the sidewalks on both sides.

(Picture from: *BRI Green Development Case Study Report (2020)*, BRIGC)

In addition, other measures to improve public space in Santiago include: investing in green spaces covering 100 square meters in old residential areas; reconstruction of abandoned plant areas; redesign of the main streets in historical and cultural centers; building more pedestrian walks and recreational spaces; improving lighting facilities; street beautification and improvement of the road system to make it more convenient and accessible (see Fig.91 and Fig.92).

Last but not least, Santiago is also promoting the development of hydrogen energy. Santiago International Airport will become the first airport in Latin America to use green hydrogen as a clean energy source. The franchisee of the airport, “Nuevo Pudahuel”, announces that it has signed a memorandum of understanding with three companies, Air Liquide, Colbún and Copec, to incorporate green hydrogen energy into the airport's operation. In this project, Air Liquide will build “electrolyzers for the production of green hydrogen”, Colbún will provide renewable energy, and Copec will install photovoltaic panels and other renewable energy sites for the airport[79].

Chapter IV Conclusion

Though separated by mountains and rivers, countries along the Belt and Road can benefit and trust each other. Since its initiation, the Belt and Road Initiative (BRI), has been gaining support and positive response from more and more countries. Cooperation projects under the framework of the BRI have built bridges for communication and outlined a beautiful blueprint for a community with a shared future for mankind.

Since the proposal of jointly developing the BRI was put forward, especially since the building of a Green Silk Road is proposed, green and low-carbon development has become a consensus for all BRI participating countries. This is the inherent requirement of carrying out the concept of green development and promoting the construction of ecological civilization. It is also an important measure to address climate change and maintain global ecological security. Transport connectivity is the basis and important safeguard for the development of the BRI, and provides facilitation for the development of other sectors. The construction and operation of transport infrastructure are inevitably faced with various ecological and environmental challenges. Therefore, the development of green transport is an inevitable way out to realize BRI green development .

The BRI green transport development is a systematic program involving multiple stakeholders, levels of government, and sectors. .This report provides case studies from the perspectives of green transport infrastructure and green mobility. Nine typical green transport infrastructure projects were selected, including the Ankara-Istanbul High-speed Rail Phase II in Türkiye, the China-Laos Railway, the PKM Highway in Pakistan, the Phnom Pehn-Sihanoukville Expressway in Cambodia, the Pulau Maura Besar Bridge in Brunei, the Peljesac Bridge in Croatia, the Bangandhu Sheikh Mujibur Rahman Tunnel in Bangladesh, the Port of Piraeus in Greece, and Mombasa Port, involving railway, highway, bridge, tunnel, port and other types of infrastructure construction. The report offers detailed

overview of the selected cases and conducts analysis on the actions taken and progress achieved in promoting green development. In terms of green mobility, Hungary, Istanbul of Türkiye, Singapore and Santiago city of Chile are selected as cases for study, involving initiatives in electric vehicles, public transport, integrated urban transport system and pedestrian streets reconstruction.

4.1 Green Transport Infrastructure

Different types of transportation projects usually have different ecological and environmental priorities. Railway and road projects are often faced with the challenge of the protection of terrestrial ecosystems, and may involve the destruction of vegetation along the line, water and soil loss, discharge of solid wastes and domestic and production waste water and gas, noise pollution, wildlife habitat destruction, etc. In addition to the ecological and environmental problems mentioned above, the development of ports and bridges also need to pay special attention to the impacts on aquatic ecosystems and fishery resources. Main measures for realizing green and low-carbon development of BRI transportation infrastructure projects include: 1) reducing resource waste and saving costs; 2)optimizing local transport structure to reduce traffic congestion and transit time; 3) carrying out technological innovation, optimizing and improving construction technology, and adopting environmental protection and energy-saving technologies; 4) implementing greening projects; 5) protecting natural environment, reducing domestic and production pollution and carbon emissions; 6) conserving biodiversity; 7) using green energy. For example, in the phase of project design, it requires mitigation measures such as afforestation and greening along the routes, especially for railway and highway projects. Project construction and operation may cause the segmentation of natural habitats, in order to avoid interference with the existing wildlife passages, the projects create special passages for wild animals by replacing roads with bridges, constructing bridge tunnels, and building high and dense

isolation fences. The Phnom Pehn-Sihanoukville Expressway, in particular, also restored fish passages by building an ecological pond bottom when crossing the river. In addition, the construction and use of transport projects may cause changes in light, noise, landforms, etc., which may have an impact on vulnerable local species. For example, in order to avoid the harm caused by the huge noise to the marine life, the Peljesac Bridge adopts the bubble curtain noise reduction measures to block the noise and avoid disrupting the activities of sea creatures.

The realization of green transportation requires the integration of green development concepts into the whole process of transport infrastructure construction and operation. Targeted measures should be taken to address different types of eco-environmental challenges with full consideration to local circumstances to minimize the impact on the environment. The mitigation hierarchy is an effective tool to reduce the impact on biodiversity and the environment, which is composed of “four-level” measures: the first level is "Avoid", that is, the project planning shall avoid environmentally sensitive areas. Thorough research and analysis have been done in the design of BRI transportation infrastructure projects to choose the most optimal routes that could avoid environmentally-vulnerable areas as much as possible The second level is "Reduce", which means to minimize the duration, intensity or scope of negative impacts through the innovative application of eco-friendly technologies and the R&D of green and environmental-friendly materials and equipment. For example, the Bangandhu Sheikh Mujibur Rahman Tunnel in Bangladesh reduces the impact on the environment by adopting green concrete proportioning and independently developing environmentally friendly shield machine equipment. The Pelješac Bridge project uses information systems such as GPS and high-tech environmentally-friendly equipment to recycle and treat waste water generated during the construction of the project. The third level is "Restore". If there is inevitable negative impact on the environment, remedial measures should be taken in time to repair the damage

caused in the construction process. For example, to make up for the damage caused by the construction of the Mombasa Port, the project team restored the mangroves in a new planting area. Finally, there is "Offset", which means to compensate for environmental damage that cannot be avoided, reduced or restored, in order to achieve no net loss (NNL) or net gain. Among them, "Avoid" is the first step and the most important level. In project planning and implementation, “Avoid” and “Reduce” actions should be taken first to minimize the negative impact of the project, followed by “Restore” actions, and finally “Offset” actions to compensate for the residual impact of the project. "Offsetting" measures should be used only as a last resort as they face challenges such as the inability to measure indirect impacts, high costs and the difficulty of balancing equity [0] .

4.2 Green Mobility

Green mobility means to adopt a travel mode with little impact on the environment to reduce urban traffic pressure, promote urban environmental protection and carbon reduction and achieve sustainable use of urban environmental resources and the sustainable development of transportation.

As a healthy and efficient way of travel, green mobility helps to save energy, improve energy efficiency and reduce pollution. For example, using public transportation such as buses and subways, car-pooling, driving environmentally-friendly vehicles, walking or cycling. In the case study of this Report, Istanbul has established a well-developed public transportation network; Singapore has established an integrated urban transport system by building an intensive bus system, developing smart transportation, promoting public transport, and implementing the green TOD model. Residents are also encouraged to use public transport. , Santiago has implemented a series of measures to encourage residents to cycle and walk.

With the development of science and technology, the improvement of urban infrastructure and civilization, people have more choices in green mobility. Energy-saving and low-carbon

vehicles such as electric vehicles, electric bicycles and shared bicycles are gradually replacing traditional fuel vehicles. For example, Hungary is committed to building an electric vehicle manufacturing center; Istanbul is promoting the independent R&D of electric vehicles and building green ports; Santiago is building electric bus corridors. Many countries and cities regard the development and promotion of electric vehicles as one of the important measures to develop green mobility. With the rapid development of new technologies such as big data, AI and cloud computing, intelligent transportation will play an increasingly important role in future green mobility systems.

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