NOVA SCHOOL OF BUSINESS & ECONOMICS

Environmental Impact Assessment
East Coast Rail Link Malaysia

Group 16

Course: 2652- Fundamentals on Environment & Sustainability

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December 9th, 2024

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1. Introduction

The East Coast Rail Link (ECRL) is a transformative infrastructure project designed to connect the east and west coasts of Peninsular Malaysia. Envisioned as a catalyst for regional economic growth, the ECRL aims to enhance connectivity, stimulate trade, and promote tourism in adjacent areas (MRL Sdn Bhd, 2024). However, as with any large-scale infrastructure development, the project poses potential environmental challenges that require thorough examination. This analysis aims to evaluate the project's potential environmental and socio-economic impacts comprehensively. Its scope encompasses two phases of the ECRL's lifecycle - construction and operation - focusing on the three sustainability domains: water, earth, and air, as well as socio-economic dimensions. The purpose is to identify significant impacts and consequently propose effective mitigation measures.

The ECRL is a collaborative infrastructure project between Malaysia and China. It is managed by Malaysia Rail Link Sdn. Bhd. (MRL), a government-owned entity under the Malaysian Ministry of Finance, which acts as the project owner and oversees its implementation and operation. The construction and engineering works are carried out by the China Communications Construction Company (CCCC), appointed through an implementation agreement. The project's financing is based on a partnership between international and local funding sources. China Exim Bank provides 75% of the total funding through a loan agreement, while the remaining 25% is sourced through local financing managed by Malaysian authorities (MRL Sdn Bhd, 2024; BRI Monitor, 2021). With an estimated cost of €15.95 billion, the ECRL is one of the most significant infrastructure collaborations between the two nations. Spanning 665 kilometers, the fully electrified rail line connects Kota Bharu in Kelantan to Port Klang in Selangor. The route traverses five states - Kelantan, Terengganu, Pahang, Negeri Sembilan, and Selangor - linking key urban centers, industrial zones, and ports (Figure 1). The construction of the project has officially started in 2017. 2018 the alignment was revised and optimized to improve efficiency and mitigate potential environmental and social impacts. By 2024, the project is expected to reach 62.4% completion, with full completion targeted for 2028 (ERE Consulting Group, 2017; MRL Sdn Bhd, 2024).

The ECRL is designed to accommodate both passenger and freight transport. Freight services are projected to generate 70% of the total revenue, while passenger traffic is expected to contribute the remaining 30%. This dual-purpose design positions the rail link as a cornerstone of Malaysia's transportation network, aiming to improve logistics, reduce travel times, and enhance regional connectivity (MRL Sdn Bhd, 2024). Beyond its transportation goals, the ECRL is strategically significant in addressing Malaysia's economic disparities. By bridging the development gap between the economically dominant west coast and the less-developed east coast, the project aims to facilitate trade, boost tourism, and support industrial growth. Thus, the ECRL is expected to create new economic opportunities, promote inclusive development, and play a vital role in Malaysia's long-term regional integration efforts (Chang et al., 2021; MRL Sdn Bhd, 2024).

The ECRL, despite its promising economic and environmental value proposition - such as reducing vehicular emissions through electric train transport and stimulating job creation - has raised major concerns due to its potentially significant negative environmental and social impacts. These concerns span both its construction and operational phases, as noted by multiple stakeholders (Yean, 2024; ERE Consulting Group, 2020; Mayberry, 2017). During construction, the project is expected to negatively impact all environmental impact dimensions. Soil erosion, sedimentation, and habitat destruction are anticipated from earthworks and deforestation (Mayberry, 2017). Increased noise and vibration from heavy machinery and construction activities, direct water pollution from machinery leaks and sediment runoff, as well as increased risk of flooding are highlighted as critical issues (ERE Consulting Group, 2020). Socio-economic disruptions include community division and economic disruptions such as workforce shortages due to route alignments and construction activities (Othman, 2024; Kassim, 2024). During the operational phase, especially the surrounding earth and air environments are expected to be negatively impacted. In these regards, biodiversity loss and negative impacts on animal welfare are projected due to route alignments and train movements (FMT Reporters, 2017), with further concerns about increased noise and vibration from train movements negatively affecting surrounding communities and animals (ERE Consulting Group, 2017).

Given the diversity and severity of these impacts, a comprehensive environmental and socio-economic impact assessment was deemed critical to devise necessary mitigation and prevention measures. These measures aim to offset or minimize the project's negative effects wherever possible, ensuring a balance between developmental benefits and environmental and social sustainability. The following analysis holistically examines all identified potentially significant environmental and socio-economic impacts across the key impact dimensions, consisting of the earth, air, water, and socio-economic dimensions. The detailed evaluation is succeeded by a comprehensive list of prevention and mitigation measures developed based on the impact analysis.

2. Air-related impacts of the ECRL

2.1 Construction Phase

For the construction phase, the identified potentially significant impacts of the ECRL project include increased noise levels, increased vibration levels, and increased air pollution. Increased noise and vibration levels are assessed to be potentially negative impacts, while increased air pollution is assessed to be a potentially moderately negative impact based on existing measurements. Increased noise levels are anticipated for receptors situated close to construction areas, mainly stemming from concreting and pilling works and high-noise machinery (Hairi et al., 2023; ERE Consulting Group, 2020). Noise is expected to increase in construction zones around stations, tracks, tunnelling works, and depot construction. Noise measurements conducted in 2017 for Section A and B and in 2020 for Section C of the ECRL project showed that the Equivalent Continuous Sound (Leq) levels ranged from 47.9 to 71.1 dBA during daytime and from 41.8 to 65.9 dBA during nighttime, indicating that the 24-hour noise level was above recommended limits (Fifth Schedule) for suburban residential areas (55 dBA for daytime and 45 dBA for nighttime) and urban residential areas (60 dBA for daytime and 50 dBA for nighttime), either during daytime, nighttime, or both, at numerous locations (ERE Consulting Group, 2017; ERE Consulting Group, 2020; King et al., 2012).

Secondly, increased ground-borne vibration levels are anticipated for receptors situated close to construction areas, mainly stemming from blasting and piling works and the movement of construction vehicles and machinery (Bowers & Lovenstein, 2022; ERE Consulting Group, 2020). As for noise, vibrations are expected to increase in construction zones around stations, tracks, tunnelling works, and depot construction. Vibration measurements conducted in 2017 for Sections A and B and in 2020 for Section C indicated that vibration levels ranged from 0.01 mm/s to 0.96 mm/s depending on time and local activities (ERE Consulting Group, 2017; ERE Consulting Group, 2020). Response curves measured in 2017 typically curve 4 to 8, implying a higher proportion is in the higher value range of the measured response curves. In 2020, relatively higher vibration levels were measured at locations exposed to vibrations from road traffic of heavy vehicles (>0.4 mm/s, Curve 4). Even though the measured vibration levels generally fell below levels of structural damage concern and met human comfort levels as recommended by the Department of Environment's (DOE) Recommended Limits for Human Response and Annoyance from Steady State Vibrations (Schedule 5), vibration is still assessed as a potentially negative impact due the inevitability of the issue for residential receptors close to construction areas as well as vibrations being generally regarded as a major concern during construction (DOE, 2007). In the ECRL project, increased vibration levels, especially from blasting works at sensitive locations and pilling works at built-up residential and other sensitive receptors, are deemed to be a major concern.

Besides noise and vibration levels, increased air pollution is anticipated for receptors situated close to construction areas, mainly from emissions of construction vehicles as well as dust generation from earthworks and construction vehicle traffic (Farhadi, 2024; Yan et al., 2023; Wieser et al., 2021; Zhao et al., 2021). Increased fugitive dust is expected to negatively affect sensible receptors close to construction sites, particularly depots, yards, and stations involving large work areas. Despite these concerns, air pollution during the construction phase is only considered to have a moderately negative impact due to the conclusion of two conducted air measurements in 2017 and 2020 for the ECRL project, both stating that air quality in construction areas was generally within the Interim Target (IT-2) Malaysian Ambient Air Quality Standard (MAAQS) 2013 limits (DOE, 2013; ERE Consulting Group, 2017; ERE Consulting Group, 2020). The more recent measurement in 2020 for Section C showed that PM10 concentrations ranged from 21 to 138 uq/m3, PM2.5 from 13 to 75 uq/m, while SO2, NO2 and O3 levels were measured below detection limits of 5 uq/m3 and 20 ug/m3 respectively (ERE Consulting Group, 2020). Also, CO was below the detection limit of 3.2 mg/m3. The measurement concluded that the increased air pollution during construction could be regarded as a low air pollution risk impact for receptors surrounding construction areas because of their generally far distance to project sites and their low population density, as well as air pollution having only a temporary impact during the construction period. Moreover, the substantial waste generation at construction sites has the potential to further increase air pollution during the construction period (Putthadee Ubolsook et al., 2024; Alsheyab, 2021). Waste generation at construction sites is generally caused by site clearing, structure demolition, and the disposal of spoil and unsuitable material. In the context of air pollution, waste generation is considered to have a moderately negative impact due to the fact that even though construction waste is overall planned to be disposed of at waste disposal facilities along the entire alignment, facilities along the alignment often differ in landfill type (sanitary or not sanitary) and waste received (all types, municipal solid waste or inert waste only) (ERE Consulting Group, 2020), implying that proper waste management along the entire alignment is not or hardly feasible.

2.2 Operational Phase

After the completion of the ECRL construction, the identified potentially significant impacts for the operational phase include increased noise levels, increased vibration levels, and reduced greenhouse gas (GHG) emissions. Again, increased noise and vibration levels are assessed to be potentially negative impacts, while reduced GHG emissions is assessed to be a potentially positive impact based on existing modellings.

Increased noise levels are expected from train movements for receptors located close to the alignment (within 50 meters) independent of line of sight (Sheng et al., 2023; ERE Consulting Group, 2017). Noise disturbances are especially expected in residential areas close to tracks and stations where transient noise from train movement significantly exceeds existing low ambient background noise levels, as well as in residential areas where receptors in adjacent high-rise buildings overlook tracks. Noise modelling conducted in 2017 for the operation of the ECRL project concluded that noise levels will exceed limits in some quieter locations (ERE Consulting Group, 2017). The conducted noise modelling showed that cumulative Leq noise from trains combined with ambient noise typically increases by less than 5 dB during the day, while at some locations, especially in quieter rural areas, noise levels could potentially increase by 10 to 16 dBA. Overall, although trains are planned to be electrical and designed to emit low noise levels, noise disturbance is anticipated for many buildings located within 50m of the alignment without noise barriers.

Additionally, increased vibration levels are expected from train movements for receptors located close to the alignment (within 25 meters) (Sheng et al., 2023; Ouakka et al., 2022). Vibration disturbances are especially expected for receptors in houses and high-rise buildings close to tracks and stations in case of no vibration mitigation or with worn wheels/tracks. In these cases, a ground-borne vibration propagation analysis conducted in 2020 concluded that receptors could be exposed to vibration levels from Curve 2 to Curve 8, depending on passenger or cargo train operation, exceeding the recommended limits of Curve 1 (ERE Consulting Group, 2020). Otherwise, with vibration levels and wheels/tracks in good condition, vibration levels are anticipated to be mainly within the recommended limits.

Lastly, contrary to all previously outlined negative impacts, the ECRL project is overall projected to positively contribute to air quality improvements in Malaysia by substituting vehicular transportation on roads with electric train transportation on rail, which is expected to lead to significant GHG emission reductions (Hairi et al., 2023; Zainuddin et al., 2022; ERE Consulting Group, 2017; ERE Consulting Group, 2020). In general, the positive effect of substituting road transportation with electric train transportation on air quality is scientifically proven to be significant based on numerous studies conducted in China over recent years (Chen et al., 2024; Zhao et al., 2021; Guo et al., 2020; Sun et al., 2019). The substitution effect has the potential to significantly reduce GHG emissions and other pollutants, such as particulate matter (PM2.5 and PM10) and gaseous pollutants (NOx, SO2, and COx). Specifically, regarding the GHG emission reduction potential of the ECRL project, different measurements were conducted in 2017, 2020, and 2024 to indicate the amount and relevance of the avoided net CO2 emissions by the ECRL project for different years (Sharif et al., 2024; ERE Consulting Group, 2017; ERE Consulting Group, 2020). Only considering the more recent measurements, in 2020, it was estimated that the project would lead to cumulative net CO2e emission avoided of about 343,566 MT CO2e/yr in 2027, while in 2024, it was estimated that the project would already lead to cumulative net CO2e emission avoided of about 343,566 MT CO2e/yr in 2024 and in 2030 to 821,290 MT CO2e/yr. However, as detailed calculations are not disclosed, the numbers must be taken cautiously. Moreover, it must be considered that the potential of the ECRL project to significantly reduce GHG emissions in Malaysia crucially depends on its final implementation date after multiple delays as logistics companies are adopting greener truck transportation methods to meet sustainability requirements in the interim, potentially diminishing the ECRL's impact upon its launch, as well as the availability of subsidized diesel fuel in Malaysia making road-based freight transport more economically attractive, further limiting the ECRL's potential to reduce emissions (Yean, 2024). Nevertheless, the ECRL project is expected to significantly improve air quality in Malaysia, even though the initially indicated reduction amounts might be lower than expected upon implementation.

3. Soil-related impacts of the ECRL

3.1 Construction Phase

Soil is one of the world's most important natural resources, critical for global food, fibre, and wood production, ecosystems, and biodiversity (Harrison et al., 2011). Hence, maintaining soil quality is a key lever in global sustainability efforts. This also becomes evident when looking at recent regulatory developments. For instance, the "Soil Strategy 2030" has been formulated in the EU, addressing several actions for sustainable soil management and representing a key pillar of the European Green Deal (European Commission, 2021). Research and various assessments have shown that infrastructure projects similar to the ECRL significantly impact soil health and quality (Goodenough & Page, 1994). While the operation of the East Coast Rail Link and other railway networks might also contribute positively to the environment, the construction phase is especially overshadowed by negative impacts. Thus, performing a thorough Environmental Impact Assessment is critical (He et al., 2009). The following section will discuss various negative impacts of the ECRL on the ecological dimension of soil by examining the construction and operation stages of the project.

When looking closer at the construction stage, one notices that most of the impacts on soil can be classified into four categories: Soil Erosion and sedimentation, Waste generation, Habitat destruction, and the Risk of peat fire. Once finished, the ECRL alignment will have a length of 665 km and connect Malaysia's east and west coasts. Along the route, the line will have to pass forests, wetlands, and many other natural obstacles (ERE Consulting Group, 2020). Hence, heavy earthworks, excavation works, and the construction of embankments, tunnels, and bridges will be required. These construction activities pose significant risks of soil erosion and sedimentation (Vikan & Meland, 2013; ERE Consulting Group, 2020). The removal of vegetation and topsoil caused by these activities is especially damaging in areas with steep slopes and high rainfall, as this will further destabilize the terrain (ERE Consulting Group, 2020). Additionally, replacing subsoils with compact fill materials may alter the soil's physical structure. Especially during the Northeast Monsoon and in flood-prone areas like Kelantan and Terengganu, mentioned construction methods increase the soil's vulnerability to sediment runoff (ERE Consulting Group, 2020). Furthermore, the negligent management of spoiled and excavated materials from tunneling further enhances degradation. Especially the previously touched upon removal of vegetation to free up the alignment for construction creates widespread problems. Soil structure heavily influences the ease with which soil can be eroded. In particular, areas covered by plant biomass are more resistant as rain and wind are dissipated, and topsoil is held together by the biomass (Pimentel & Burgess, 2013). Also, from a global perspective, the loss of soil from land surfaces is far-reaching, as it reduces the productivity of all natural ecosystems and represents one of the most serious threats to world food production (Pimentel & Burgess, 2013).

The construction of the ECRL is expected to generate substantial waste resulting from site clearing, demolition of existing structures, and excavation works. Next to wastes directly connected to construction activities, there will also be wastes from worker camps and site offices that accommodate the large workforce involved in the railway construction (ERE Consulting Group, 2020). Accordingly, there will be various types of waste, including construction debris, biomass, excavated spoil, and concrete and chemical waste from unused materials and fuel spills. Hence, improper disposal could contaminate soil, harm ecosystems, and even increase fire hazards. If left unmanaged, waste, in general, might alter soil composition and lead to compaction, reduced fertility, and disrupted drainage patterns (Shamali De Silva et al., 2023). Even more concerning is the improper handling of chemical waste, which bears a direct contamination risk and might potentially affect microorganisms vital to soil health. Lastly, certain construction waste, such as plastic and metal scraps, might lead to entanglement or be mistaken for food, cause injury or death, and, in the long term, even affect the food chain (Huerta Lwanga et al., 2017).

The previously mentioned construction methods also pose significant risks of habitat destruction, particularly in ecologically sensitive areas along the alignment. Next to peatlands and mangroves, the ECRL will cut through protected forests, causing significant concerns (Mayberry, 2017). The Malaysian rainforest is believed to be among our planet's oldest and most biologically diverse forests. Because of forests like this, Malaysia is recognized as one of 12 mega-diversity countries with many species occurring in unusually high densities (WWF Malaysia, 2024). For instance, Malaysia is home to the Malaysian Tiger, Bornean Elephants, and the Bornean Orangutan, which has been classified as critically endangered by the IUCN Red List (WWF Malaysia, 2024). Next to being essential in providing our planet with its rich biodiversity, forests absorb and store large quantities of CO2 and hence are a key lever in combating climate change (Jacob, 2020). Unfortunately, deforestation is a major concern in Malaysia, as the country which, according to WWF Malaysia (2024), once was almost entirely covered with forests, is now only covered by about 54%. Consequently, constructing a major infrastructure project entails challenges and aggravates current environmental issues. Not only does removing vegetation increase Malaysia's deforestation, but it also results in a direct loss of habitat for all kinds of species (WWF Malaysia, 2024). Besides forests, wetland and mangrove areas also will be passed by the ECRL. These areas typically are critical in maintaining biodiversity but are also extremely vulnerable to impacts of soil compaction and pollution (Denny, 1994). Hence, to preserve Malaysia's long-term biological richness and diversity, it will be crucial to consider the mentioned impacts.

Despite the country's relatively small size, Malaysia has the 9th largest peat area in the world, which, with a size of over 25,000 Km^2, covers approximately 8% of the country (Construction Research Institute of Malaysia, 2019). As the composition of peat and organic soils is very different from that of other soils, like soft clay, construction is usually more challenging and entails some risks (Construction Research Institute of Malaysia, 2019). Peatlands are highly flammable, especially due to their organic composition and accumulation of dry plant material. Thus, when working with heavy machinery, the potential for ignition always exists. The impacts of a potential peat fire are significant for various reasons. Next to leading to massive greenhouse gas emissions, fire can also cause significant damage to soil integrity, disrupting ecosystems dependent on these habitats. Lastly, with fire, there also always remains the risk of an uncontrollable spread, affecting adjacent ecosystems.

3.2 Operational Phase

With the overall project completion targeted for January 2028, the ECRL will soon transition into the fully operational stage. As the impacts of construction do not play a role from that date onwards anymore, questions regarding the operational impact on the environmental dimension of soil arise. The environmental impact assessment of the operational stage shows that anticipated impacts are by far not as significant as for the construction stage, but a few risks still remain, namely decreasing biodiversity, vibration, and waste generation (ERE Consulting Group, 2020; ERE Consulting Group, 2017).

While biodiversity was already affected by activities of the construction stage, the operational stage further exacerbated this issue. Especially the fragmentation of ecosystems caused by the railway track and train movement creates a physical barrier to wildlife. The alignment restricts access to feeding, breeding, and migration corridors and isolates animal populations. In the long run, this may lead to genetic isolation and an increasing risk of local extinctions (Templeton et al., 1990). Next to the direct fragmentation of forests, vibration caused by passing trains might further impact animals close to the railway. As research suggests that increased levels of noise and ground-borne vibration can exert severe stress levels on animals, a negative impact on animal welfare can be assumed. The constant operation and vibration of trains might deter sensitive species from inhabiting areas near the alignment. Lastly, waste also plays an important role during the operational stage. As the ECRL is predicted to transport 5 million passengers annually by 2030, a significant increase in generated waste across the 20 train stations can be expected (ERE Consulting Group, 2020). Hence, implementing an efficient waste management network handling these amounts of waste will be required to avoid the previously mentioned environmental impacts of waste.

4. Water-related impacts of the ECRL

4.1 Construction Phase

Although the impact of the ECRL on water is not as immediately apparent as it is for air and soil, it is still worth examining as the ECRL alignment crosses a total of 27 river basins, in addition to "numerous tributaries, irrigation canals, earth drains, small streams, and ponds" (ERE Consulting Group, 2017, p.19). This necessitates the construction of 80 bridges, some over major rivers such as Kelantan, Terengganu, Dungun, Kemaman and Pahang, with lengths exceeding 300 meters. Additionally, 88.8 km of the route will be elevated to address challenges posed by flood-prone areas, swamps, and urbanized zones (ERE Consulting Group, 2017).

While the consideration of water-related factors significantly influences the planning and construction of the ECRL, the project's impact on the aquatic systems of the surrounding areas is even more substantial. The lack of published data on its water consumption is a critical shortcoming that hinders a full assessment and necessitates the reliance on insights from similar projects (ERE Consulting Group, 2017; UN Environment Program, 2023). Evidence from a comparable Chinese railway project suggests that 90% of water use occurs indirectly, mainly related to upstream processes such as metal smelting and the manufacturing of transport equipment (Cheng et al., 2020). Bridges consumed 58% of water during construction, far more than rails (16.5%) or electric multiple units (15%). Despite Malaysia's relatively low water stress ranking (WRI 2023), the ECRL's scale suggests substantial water demands. The Chinese rail project, with only one-fifth of the length of the ECRL, consumed 54.95 billion liters - 7.48 times Malaysia's 2022 domestic water use (7.35 billion liters), highlighting the potential magnitude of the ECRL's water footprint (Cheng et al., 2020; Statista, 2024).

Two adequately measured aspects are the risk of water quality degradation and the increased risk of flooding (ERE Consulting Group, 2017). These issues are of significant importance due to their far-reaching ecological, economic, and social implications. For example, eight downstream water treatment plants, key agricultural zones like Kemasin and Semarak, and aquaculture farms in Kelantan, Terengganu, and Pahang could be disrupted if the local water quality declines. Socially, recreational areas such as the Lentang Forest Recreational Park, which are vital to local tourism and community well-being, also face potential impacts (ERE Consulting Group, 2017; Lucas et al., 2017).

In order to effectively address the concerns of these stakeholders, it is essential to identify and mitigate the various sources of pollution that may arise throughout the project's life cycle. During the construction phase, soil erosion and sedimentation caused by insufficient pollution prevention and mitigation measures pose the greatest risk to water quality (Lucas et al., 2017; ERE Consulting Group, 2017). This leads to a range of water-related impacts, including reduced water quality, diminished river carrying capacity, decreased water treatment plant efficiency, reduced aquaculture productivity, and lower recreational value of affected water bodies (ERE Consulting Group, 2017). Additionally, wastewater generated from tunnelling activities is expected to contribute to increased levels of suspended particles (5.000–10.000 mg/l), as well as pollutants like "acidic runoff, heavy metals, radioactivity, alkalinity, nitrogen, oil, chemicals and polypropylene fibres" (Meland, 2013, p.475; ERE Consulting Group, 2017; He et al., 2023). Runoff from batching plants further exacerbates the issue, often carrying high concentrations of suspended solids and cement residues that can degrade water quality. Maintenance activities involving machinery and vehicles add to the risks, including the potential for accidental oil spills, leakage of hazardous substances, or improper discharge and spillage, all of which could contaminate nearby water systems (ERE Consulting Group, 2017; He et al., 2023). Furthermore, wastewater from workers' camps, including sewage and sullage, presents a significant threat. Without proper wastewater management, there is a high likelihood of introducing organic matter and pathogens into the aquatic environment (ERE Consulting Group, 2017; Wang et al.,2023).

4.2 Operational Phase

Once the ECRL transitions into its operational stage, expected in 2028, the potential sources of pollution will shift significantly. During this phase, the responsible authorities identify stations, depots, yards, and maintenance bases as key contributors to water pollution risks, aligning with research findings (ERE Consulting Group, 2017; Radziemska et al., 2020). For instance, wastewater generated from cleaning locomotives and railcars may contain pollutants such as soot, mineral dust, and cleaning agents (ERE Consulting Group, 2017; Radziemska et al., 2020; He et al., 2023). With regard to wastewater treatment, the authorities state in their report: "The sewage treatment facilities at the stations will be designed to meet regulatory requirements and cater to future expansion, with capacities of 1400 PE, 250 PE, and

150 PE" (ERE Consulting Group, 2017, p.39). However, a closer look at projected user numbers suggests that while these capacities may meet regulatory requirements, they may fall short of actual demand. Thus, without timely expansion, the risk of contamination from overburdened sewage facilities will increase significantly.

In addition to water quality degradation, the increased risk of flooding represents a significant environmental concern associated with the ECRL, particularly given that "a substantial portion of the alignment in Kelantan, Terengganu, and Pahang is in flood-prone areas" (ERE Consulting Group, 2017, p.20; Sa'adin et al., 2016). The east coast of Peninsular Malaysia is frequently affected by floods during the northeast monsoon season, which occurs from November to March. This risk is expected to intensify with the progression of climate change (Sa'adin et al., 2016; ERE Consulting Group, 2017; Ochsner et al., 2023). The ECRL construction has the potential to exacerbate flooding through several mechanisms. Construction activities may interfere with ongoing flood control projects in these regions, while constructing embankments, buildings, stations, and piers can obstruct or redirect natural floodwater paths, potentially leading to water accumulation. Additionally, the large amount of excess earth material from activities like tunnelling and hill cutting has the potential to cause the "alteration of water bodies and localized flooding" (ERE Consulting Group, 2017, p.27). Existing culverts and bridges may be insufficient to manage high flood volumes, increasing the likelihood of blockages. In addition, construction activities can block drains or alter the natural flow of streams, which is exacerbated by increased surface runoff from impervious surfaces such as paved areas (ERE Consulting Group, 2017; Malaysian National News Agency, 2024; MRL, 2024).

5. Socio-Economic Impacts of the ECRL

5.1 Construction Phase

The construction and operation of the ECRL does not only impact its environment on the dimensions of water, earth and soil. A crucial element that requires thorough analysis is the impact on society on local, regional and national dimensions. Accordingly, this section examines the socio-economic impact of the ECRL in the construction and operational stages. As the ECRL significantly cuts through the landscape due to the sheer size of the tracks and the incorporated enclosures, there is a negative impact on over 35,000 households along the entire route. A key dimension is the physical division of villages, which restricts the previously seamless access of inhabitants to certain parts of communities, such as stores and educational institutions. These factors reduce communities' interconnectedness and could even reduce their feeling of unity as local commutes become more complex and inconvenient (ERE Consulting Group, 2020). Examples can be observed in the villages of Kg. Orang Asli Bukit Jenuk and Kg. Lumut in the state of Selangor. These indigenous communities are severely disrupted, as access to parts of their villages, such as religiously significant sites, is restricted or unattainable. As religious practices are key elements of these communities, the ECRL decreases their ability to engage with parts of their culture, decreasing their sense of belonging (ERE Consulting Group, 2017). Research by Judijanto et al. (2024) confirms these implications, as their findings underline the significance of religious practices to community cohesion. Overall, community division is a significant challenge with severe negative implications. However, another key negative implication of the physical division is the disrupting effect on agriculture, which is discussed next.

The physical division through the ECRL goes beyond negative social implications, as certain farm plantations will have their single units of land divided. This makes it unattractive for farmers and, in the worst cases, unfeasible to maintain operations, as scalability benefits from heavy machinery cannot be leveraged anymore. Therefore, affected farms will need to either relocate or shut down. As most affected farmers depend on income from farming activities, the negative financial impact is substantial, and some communities lose the single source of income they depend upon. The case of the Chemomoi plantation in the state of Pahang exemplifies this negative impact, as it experiences significant decreases in the efficiency of palm oil production (ERE Consulting Group, 2020).

The third key negative impact during construction is the lack of transparency regarding the project's economic feasibility and geoeconomic strategic positioning, leading to a controversial public image. One example is the limited disclosure of costs, which tripled since the initial feasibility study before slightly decreasing again without indicated reasons (Kassim, 2024). Furthermore, as a Chinese state-owned bank finances 85% of the project, there are concerns about Malaysia's dependency on long-term debt, especially since the economic feasibility of the ECRL has not been confirmed (BRI Monitor, 2024). In addition, although the projects' agreement dictates the involvement of at least 40% of Malaysian contractors, there is public mistrust that subcontracts are transferred back to Chinese companies, which would decrease the effective benefit to the regional economy (BRI Monitor, 2024; Zainuddin et al., 2022). Lastly, another less significant concern is the negative impact on road traffic, as construction work will hinder regular traffic on certain routes and lead to overcrowded roads. Hence, less efficient routes will be necessary temporarily, negatively impacting commute and transportation times (ERE Consulting Group, 2017).

Although there are mainly negative socio-economic implications, the construction of the ECRL requires the involvement of different contractors and subcontractors to implement the project, which leads to increased regional economic activity (Zainuddin et al., 2022). Hence, business and job opportunities are created, although, as previously discussed, the degree of involvement of Malaysian companies is not certain. Nevertheless, construction activities require machinery and materials, thereby increasing demand for local suppliers (BRI Monitor, 2024). Furthermore, various industries along the value chain experience increased demand, exemplified by the need for local logistics companies. Additionally, even some industries unrelated to construction activities benefit from the increased presence of construction workers. Therefore, temporary workforces increase the demand for local economies by increasing local expenditures on basic needs such as food and accommodation (Zainuddin et al., 2022; BRI Monitor, 2024).

5.2 Operational Phase

During the operational phase of the ECRL, the socio-economic implications are primarily positive. However, two key issues remain safety concerns and the extension of limited transparency from the construction to the operational stage. Concerns have been raised regarding safety, addressing the potential of humans and farm animals crossing railway tracks outside predetermined areas and accidental spills of hazardous freight. This danger can potentially lead to severe health risks, injuries and even deaths (ERE Consulting Group, 2020). Moreover, criticism of the lack of transparency and potential influence of foreign Chinese institutions extends to the operational stage. Hence, as the operation of the ECRL will be implemented by a joint venture between the CCCC and MRL with equal ownership, and the CCCC has access to the technical expertise and technology required for operation, the Chinese government can exert control over operational decisions. An example of this could be an increased focus on freight transport to the benefit of specific trading routes, which could favor certain economic and geopolitical agendas at the cost of regional benefits. Furthermore, limited disclosure on accountability mechanisms, regulatory compliance, involved cost structures, and the profitability of operations decreased public trust in the economic feasibility of the operation and Malaysia's independence from foreign entities. This criticism is in line with issues related to the construction and is a critical source of controversial debates (BRI Monitor, 2024).

On the other hand, there are various significant positive socio-economic implications resulting from the operation of the ECRL, which are discussed next. Hence, Malaysia directly benefits from the railway project through a more efficient mode of transportation for people and freight. As such, passengers benefit from faster commutes to and from work and generally decreased travelling times throughout the country. An example is the route from Kuala Lumpur to Kota Bharu, where travelling time decreases to four hours, compared to up to twelve hours before the project (ERE Consulting Group, 2020). Furthermore, the increased usage of railways as a mode of transport associated with the project leads to a shift from the use of automobiles. Therefore, road traffic is expected to be less overcrowded, especially in periods of increased congestion, such as bank holidays (BRI Monitor, 2024; ERE Consulting Group, 2017).

Moreover, as the ECRL improves the connectedness within the country and offers transit to other railway lines at certain stations, access to tourist attractions throughout the country, especially in the East Coast region, will be improved (Railway Technology, 2024). An example of the expected boost in tourism is the station at Mentakab, which will provide a more convenient connection to reach the Taman Negara National Park, which is a vital element of the tourism industry in Malaysia (ERE Consulting Group, 2017; Brander & Yeo, 2021). In addition, although the East is generally more viable for investors due to lower costs in acquiring land for economic purposes, the lack of infrastructure hindered industrial development. As the ECRL will enable efficient transportation of goods, materials and services between East and West, it will enhance economic productivity and attract new investments. An example is the improved connection between key ports such as Kuantan Port and Port Klang in the East and West, key industrial hubs for Malaysia (BRI Monitor, 2024; ERE Consulting Group, 2017).

Another key result expected to enhance Malaysia's economy is increased local business and job opportunities across various industries along the ECRL alignment. This is exemplified by opportunities at new stations, where demand for the availability of retail and gastronomy will increase (ERE Consulting Group, 2020). Furthermore, Economic Accelerator Projects implemented by the Malaysian government aim to further aid economic progress along the ECRL alignment by supporting the development of industrial parks and logistics hubs (Siew & Zhang, 2021). In addition, as Abd Aziz et al. (2018) argue, railway projects such as the

ECRL increase urban development along its alignment, enabling accessibility to rural areas and concentrated economic growth. Furthermore, it also balances urban development between the developed West and underdeveloped East by facilitating even access to national economies. Findings by Bruinsma et al. (2008) underline this trend, as cohesive regional urbanization and social inclusion are pointed out as the main advantages of railway projects. Overall, the portfolio of socio-economic benefits is represented by an expected GDP increase of 2.7% until project completion (Kassim, 2024) and 3.78% by the year 2047 (MIDA, 2024).

6. Recommendations

6.1 Prevention and Mitigation Strategies for Air-Related Impacts

To address potential negative air-related impacts during the construction of the ECRL, targeted measures to minimize noise, vibration, and air pollution are recommended. For noise and vibration, low-noise and low-vibration equipment and construction techniques, such as silent or vibratory pile drivers, should be employed (Buck, 2023). Temporary noise barriers and equipment enclosures can further mitigate impacts (Buck, 2023; FHWA, 2017). Specific measures should target dust and emissions to decrease air pollution. Dust suppression techniques, including water spraying on roads, stockpiles, and exposed surfaces, should be prioritized alongside the enclosure of transported materials and phased site clearing (ERE Consulting Group, 2020; Yale EHS, 2009). Speed limits and temporary site roads should also be implemented to minimize emissions and dust from construction traffic (ECY WA, 2016). Additionally, waste management should exclusively be based on sustainable practices, including the reuse of suitable materials, recycling of recyclable materials, disposing waste only at approved facilities, and prohibiting open burning to reduce air pollution from construction waste (ERE Consulting Group, 2020). The proposed measures are designed to control pollution levels within the Malaysian Ambient Air Quality Standard, minimizing environmental and community disturbances.

During the operation of the ECRL, it is advised that targeted measures to minimize noise and vibration are implemented to effectively manage potential negative air impacts. To minimize noise impacts, noise barriers should be implemented, especially semicircular sound barriers near sensitive areas within 50 m from alignment and with direct lines of sight (Liu et al., 2019). The use of continuously welded tracks and dampers can further reduce operational noise, while it is also recommended to deploy low-noise trains with advanced noise-dampening technology and conduct regular maintenance of rolling stock components to ensure minimal noise and vibration levels (Pultznerová & Ižvolt, 2014). To mitigate vibration impacts, incorporating vibration-isolated tracks, such as under-sleeper pads, should be considered (Lutz Auersch, 2024). Advanced suspension systems for high-speed trains can further reduce vibrations (Jin et al., 2020). In addition to the mentioned solutions, both continuous noise and vibration monitoring systems should be employed to ensure compliance and adapt operations if needed (ERE Consulting Group, 2020). Finally, concerning improving air quality, the artificial-intelligent (AI)-powered railway control and dispatching system (APRCDS) represents an attractive tool for ECRL operational organizations to adopt as it can effectively optimize the overall energy efficiency and resource utilization rate, thereby reducing carbon emissions, by improving the matching degree of multi-mode railway transportation capacity resources (Liu et al., 2024). ECRL operational organizations can implement the APRCDS tool by deploying sensors, IoT devices, and communication systems along the whole track alignment, establishing a central data hub, aggregating all relevant data from the devices, and developing and integrating a tailored AI platform.

6.2 Prevention and Mitigation Strategies for Soil-Related Impacts

Throughout this report, it has become evident that the soil-related impact of the ECRL is severe. While all the addressed impacts must be considered, soil erosion, waste generation, and biodiversity loss have been identified as the most important ones (ERE Consulting Group, 2020). This is mainly due to their profound interconnected effects on ecosystems and long-term environmental health. Thus, implementing strategies to prevent and mitigate the far-reaching impacts is vital. As highlighted before, frameworks like the EU Soil Strategy are central to safeguarding the long-term preservation of soil health and serve as a guideline in EU member states. In Malaysia, the governance and prevention of environmental pollution primarily fall under the Environmental Quality Act 1974 (Malaysian Department of Environment, 1974). While this act represents a milestone in environmental legislation for Malaysia and is a foundational law for environmental governance, its soil-related measures are limited. Therefore, going beyond what is required by local regulations and following a more comprehensive approach when preventing soil-related impacts is recommendable.

Various mitigation strategies would improve the relevant impacts. To prevent erosion and sedimentation of soil, vegetative buffer zones, mulch, cover crops, and grass cultivation have proven to be effective mitigation measures in Asia (Nasir Ahmad et al., 2020). In particular, these activities help to conserve soil moisture, reduce surface runoff, and decrease the impact of rainfall (Nasir Ahmad et al., 2020). The mitigation of unmanaged waste also is central to conserving soil health. Tools like the European Waste List can be used to properly manage and categorize the various types of emerging waste (European Commission, 2014). In the next step, the waste could then be organized according to the waste hierarchy (European Commission, 2022). This would allow reusing, recycling, and recovering suitable wastes and reduce the amount of disposal. Implementing this strategy could be further enhanced by using AI to assist in identifying and categorizing waste, which might help mitigate pollution and potentially save costs (Na et al., 2022). Lastly, to minimize the impact on biodiversity, it is crucial to identify critical habitats such as protected forests and peatlands and minimize construction within these areas. In the most critical habitats, re-alignment of the track should be considered, but even if not possible, fragmentation of ecosystems should be avoided as much as possible. While the ECRL already plans the construction of tunnels and bridges at some track segments, limiting habitat fragmentation should be focused even further. By installing arboreal bridges and implementing under and overpasses for animals, wildlife connectivity and biodiversity during the operational stage can be maintained, as shown by similar studies (Bond & Jones, 2008). Post-construction reforestation and rehabilitation initiatives along the alignment could further ensure the sustainable restoration of the region's ecosystem.

6.3 Prevention and Mitigation Strategies for Water-Related Impacts

The main water-related impacts are water pollution and increased risk of flooding, which require targeted mitigation measures. The possible responses to water pollution are as diverse as the sources of pollution themselves. One of the main sources of water pollution - soil erosion and sedimentation - was already discussed under the soil section, along with the mitigation measures. The wastewater generated by tunnelling and batching plants should be treated using sedimentation basins to reduce total suspended solids (Vikan & Meland, 2013; He et al., 2023). Settling basins and adding filtration and chemical coagulation can further lower the TSS levels (Mooselu et al., 2023). Preventing pollution from machinery and vehicle maintenance requires designated areas with spillage controls and careful storage and handling of oils, lubricants, and other materials to avoid environmental contamination (Radziemska et al., 2021; ERE Consulting Group, 2017; He et al., 2023). Using "aqueous detergent cleaning solutions or steam cleaning, or […] aliphatic cleaning solvents" (IFC, 2007, p.8) further minimizes the risk of water pollution. Regular training on eco-friendly practices, waste disposal, and chemical handling equips personnel with the knowledge to minimize environmental harm and fosters greater environmental awareness (IFC, 2007).

To address the growing flooding risk, various structural measures were implemented. A total of 71.84 km of elevated sections, cross-culverts at strategic locations and bridge piers were constructed to reduce backwater effects and mitigate flood risks. Temporary drainage systems divert runoff during construction, and on-site detention facilities regulate surface water during operation (ERE Consulting Group, 2017; MRL, 2024). However, non-structural measures have not yet been fully leveraged and should receive greater attention. In this context, emerging AI technologies represent a powerful tool, particularly for real-time flood monitoring and early warning systems (Kim et al., 2023). By deploying IoT sensors in flood-prone areas, it becomes possible to monitor critical data such as water levels, rainfall, and flow rates in real time. AI-based predictive models can then analyze this data to predict imminent flooding and provide timely alerts to local communities, rail operators, and authorities (Chen et al., 2022; Kim et al., 2023). Additionally, comprehensive awareness campaigns are vital to educate communities on flood risks and preparedness. Finally, affordable flood insurance programs for high-risk communities offer additional protection, addressing the social and economic impacts of flooding (Reeves et al., 2019; World Bank, 2012).

6.4 Prevention and Mitigation Strategies for Socio-Economic Impacts

Due to the severity of their impacts and the number of people affected, the division of communities, disruption of agriculture, and transparency concerns will be addressed further in this section to discuss recommendations for potential mitigation measures. Accordingly, the division of villages leads to permanent changes in the environment for affected villages. Hence, a key recommendation is to create over- and underpasses for pedestrians and vehicles to cross the tracks of the ECRL freely. This has been partly planned but needs to remain a key focus during the remainder of the construction to ensure successful completion. Furthermore, a crucial strategy should be to encourage active community engagement when relocation is required and during the construction of over- and underpasses. Hence, by targeting the participation of representative community members in initiatives and decisions, a focus on needs as expressed by the affected communities is possible to, for example, ensure that the construction of over- and underpasses is in line with requirements. This could ensure alignment of implemented strategies and policies with the opinions of community members and reduce the negative impact (ERE Consulting Group, 2020; Erkul et al., 2016). This recommendation is also crucial in the case of farm fragmentation, as it is associated with community division and has similar implications. However, another key recommendation for farm fragmentation is appropriate reimbursement. Accordingly, currently, farmers are only reimbursed for the fraction lost through the alignment. A more effective strategy would be reimbursing farmers for the entire plot to enable investment into viable alternatives (ERE Consulting Group, 2020).

The criticism of transparency requires strategies to improve public disclosure and increase trust from the Malaysian population. A crucial tool that should be used to achieve these goals is the use of technology and generative AI during construction and operation. An example of successful implementation can be observed in the Smarter London Together project, where technology such as generative AI is used to create platforms and interactive dashboards for real-time monitoring of key performance indicators and public disclosure of project progress. Hence, this offers significant potential to enhance the ECRL's transparency through automatic accountability mechanisms and increase public trust. Although this implementation would likely be capital and time-intensive, it represents a feasible and effective long-term strategy (Greater London Authority, 2018). However, the first reasonable step could be to implement regular reporting schedules for relevant information (ERE Consulting Group, 2020).

7. Conclusion

The ECRL represents a remarkable milestone for Malaysia, enabling economic growth and prosperity by facilitating nationwide connectivity. Although the operation of the ECRL is primarily associated with positive socio-economic and air-related implications, the project is overshadowed by severe negative impacts across all four dimensions, summarized in Figure 2 (Appendix). Particularly, this report identified key air-, soil- and water-related impacts, especially highlighting pollution, losses in biodiversity and habitat fragmentation. Furthermore, the division of communities, disruption of agriculture, and lack of transparency constitute key socio-economic concerns. Due to the controversial nature of this large-scale infrastructure project, adequate mitigation measures are crucial to decrease the negative implications and leverage its potential to transform Malaysia's economy. Accordingly, key mitigation measures have been analysed, while the practical application of technologies such as AI is recommended as an underlying tool. Furthermore, successfully developed policies have been recommended as guiding frameworks to enhance currently implemented construction practices. Ultimately, the ECRL requires comprehensive management of ecological and economic dimensions to minimize the adverse environmental and social implications and enable sustainable long-term benefits for Malaysia's economy and society

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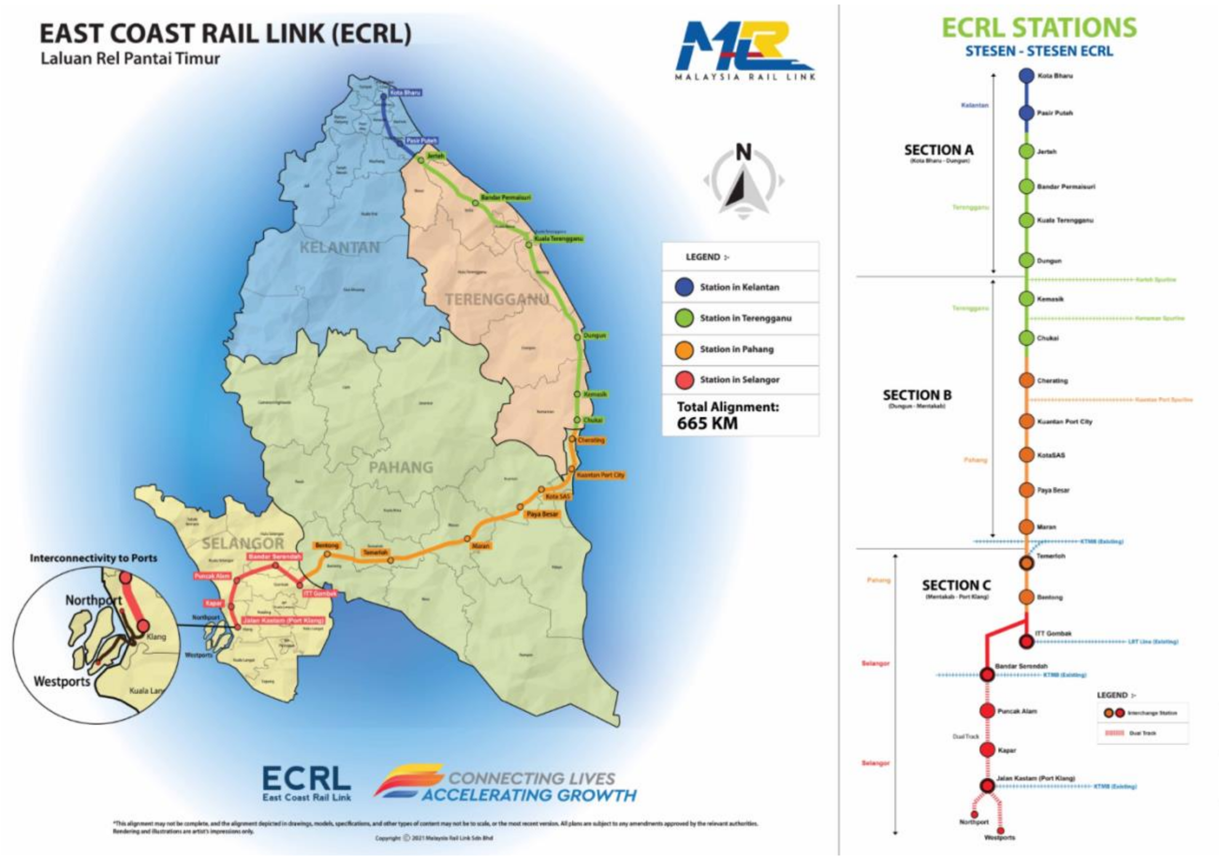
Appendix

Figure 1 - Route of the ECRL



Source:

Malaysia Rail Link Sdn Bhd. (2024). *ECRL Alignment*. Malaysia Rail Link; Malaysia Rail Link Sdn Bhd. https://www.mrl.com.my/en/alignment/

Figure 2: Overview of key impacts

Overview Potentially Significant Positive and Negative Impacts

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Diverse set of negative impacts for construction to consider, while positive impacts for operation expected to predominate

Stage	Impact Dimension	Potentially Significant Impacts	Assessment*	Potential Prevention & Mitigation Measures
Construction Stage	Earth	• Soil Erosion & Sedimentation • Waste Generation • Habitat Destruction	Negative Negative Negative	• Optimisation of alignment to avoid hilly terrain • Reuse of biomass as mulching for erosion control landscaping • Phasing of site clearing and vegetation removal
	Air	• Noise • Vibration	Negative Negative	• Temporary noise barriers / hoardings • Use of low noise pilling methods
	Water	• Direct Water Pollution • Risk of Flooding	Negative Negative	• Effective treatment for wastewater from batching plants & tunnelling • AI-based predictive models for flood prevention
	Socio-Economic	• Division of Communities • Disruption of Agriculture • Job & business opportunities	Negative Negative Positive	• Consultation & engagements with affected communities • Provision of tunnels to avoid fragmentation
Operational Stage	Earth	• Decreasing Biodiversity • Vibration	Negative Negative	• Provision of wildlife crossings • Use of continuous welded tracks
	Air	• Noise • Vibration • Air Quality Improvement	Negative Negative Positive	• Installation of noise barriers at railway / receptor boundary • Installation of vibration isolation btw. tracks & supporting structure
	Socio-Economic	• Efficient People Transport • Efficient Freight Transport • Job & Business opportunities	Positive Positive Positive	

*Preliminary assessment based on existing reports and measurements

Legend: ● Positive Impact ● Negative Impact

Note:

Overview of Potential Major Positive and Negative Impacts During the Construction and Operational Phases of the ECRL: For clarity and focus, medium-significance impacts have been omitted.