Climate change vulnerability and adaptation for the Singapore-Malaysia high speed rail system

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n recent years, there has been increasing interest amongst policy makers across the globe in building High Speed Rail, including in Malaysia. In the creation of this new form of transportation, Malaysia needs to ensure that the new HSR will cope and adapt to climate change. In addition, the complexities of climate change and predictions of climate model outputs have introduced an additional measure of uncertainty for railroad operators\(^1,2\). Extreme weather has affected railway operations and safety, including fatalities, injuries and property damage. Despite climate change posing serious challenges to infrastructure projects, little research has been conducted in Malaysia into how vulnerable it will be especially in respect to transport infrastructure. It has been widely recognized that there is a need to integrate consideration of climate change and its impacts in development policies and projects\(^3\). Decisions made today – for example, in the creation of new infrastructure or other assets need to occur in a way which ensures that the outcomes of those decisions are robust enough to cope with, or adapt to, changing climatic conditions in the future\(^4\).

High Speed Rail from Kuala Lumpur, Malaysia to Singapore (HSR) which is still in its planning
stage (at the time of writing), would be the first of its kind in Malaysia. Prime Ministers of Malaysia and Singapore jointly announced the project of HSR on February 19, 2013 and described the HSR as a ‘Game Changer’. The project’s target is to be fully operational by 2020. The plan of the HSR network, devised by Malaysia’s Land Public Transport Commission (SPAD), is to have seven stations, two Terminus stations, which are in Kuala Lumpur and Singapore. There will be five transit stations, one each in Negeri Sembilan, Malacca and three in Johor. The HSR will have two operation systems, which are express (non-stop), and transit journey from Kuala Lumpur to Singapore. The express journey time is 90 minutes, while the transit operation will have seven stops including at terminus station with a 120 minutes journey time. This journey time does not include the waiting time and immigration processing. The trains are expected to run at 300km/hour or faster. However, average speeds will be lower due to the slower speed when approaching stations.

Baseline alignment has been developed by SPAD as shown in Figure 1, but the detailed alignments remain confidential at this stage. The HSR will have a dedicated line, which is proposed to be a double track on a standard gauge.

The HSR project is believed to impact the way of life for Malaysians and Singaporeans in terms on social, politics and economics. According to SPAD, “the main objective of HSR is to reduce travel time between Kuala Lumpur and Singapore to 90 minutes by strengthening the link between two of Southeast Asia’s most vibrant and fast-growing economic engines compared to the five to six hours journey time by road or eight hours by conventional train”. Although plane travel time is 90 minutes similar to the proposed HSR, the hassle of long hours waiting before and after departures will actually give total journey time of 2.5 hours by plane. On the contrary, passenger can board the HSR at the railway station 15 minutes before departure (see Figure 2). The introduction of HSR will increase daily journeys between KL and Singapore will benefit the people and economies of both countries.

Figure 1: Proposed High Speed Rail Malaysia to Singapore

![Proposed High Speed Rail stations](image-url)
The main objective of this study is to identify the risks and vulnerabilities imposed on the high speed rail system caused by local conditions including topographical, geological and climate change of the proposed HSR route in Malaysia. The study also aims to evaluate how the infrastructure design can satisfy all the operational requirements given the climate impact issues. In carrying out this study, critical literature reviews were carried out. The data of Malaysia HSR are derived from SPAD, and the data of weather are supplied by Malaysian Meteorological Department in order to study the impact of climate change and operational requirement to the design of the infrastructure. The risks due to climate change have then been analysed for potential actions proposed to mitigate the impact.

Climate, Geography and Lessons Learnt

Malaysia is divided into two parts, Peninsular Malaysia and East Malaysia (refer to Figure 3), which are separated by the South China Sea. Peninsular Malaysia however is further split into two parts, the west and east coasts, by the Titiwangsa Mountains. The climate in Malaysia is dominated by two monsoon regimes namely the northeast monsoon and southwest monsoon. The northeast monsoon circulates during the months of December, January and February, which is Malaysia’s wettest season and the period where the most flooding occurs. Meanwhile the southwest monsoon occurs between the months of May and September, the drier period for the whole country leading to droughts in this period. Being in the equatorial zone and a tropical country, the average temperature throughout the year is constantly high (26°C) plus high humidity. Malaysia also has very heavy rainfall which is more than 2500mm per year.

“Warming of the climate system is unequivocal and since the 1950s, many of the observed changes are unprecedented over decades to millennia”⁶. According to the Malaysia Meteorological Department⁷, earth surface temperature records have clearly indicated that the climate of the earth is warming, with the rise due to the increasing concentration of greenhouse gases (GHG) in the atmosphere. Thus in the next 50 year, Malaysia will experience higher temperatures, changing rainfall patterns, rising sea levels and more frequent extreme weather events ranging from drought to floods.

The famous Malaysian rail jungle (east coast line) (refer to Figure 4), which is operated by National Malaysia Railway (KTM) was disrupted for almost six months due to the massive flood
Figure 3: Malaysia Map

Figure 4: Malaysia Rail Map
in December 2014. The damage included the railway quarters, signalling, tracks, locomotives, machinery and rolling stock. The disruption affected thousands of workers, traders and children going to school. There is still one stretch of line still not back in operation due to the collapse of the railway bridge in Kemubu, Kelantan (see Figure 5). Operation of the train service in the east coast was expected to be fully operational with the completion of the railway of the new 250m long bridge across the Nenggiri River, which is expected to cost RM30 million. This incident should give a lesson to the railway industry and policy makers that extreme weather can have a severe impact to the transportation operations as well as to their infrastructure. Rebuilding railway infrastructure is not easy and is very costly, thus to provide a reliable railway system into the future, studies of the impact of climate change is needed. From these studies, the adaptation of railway infrastructures and rolling stock to the climate change could be established.

Vulnerability of High Speed Rail Infrastructure in Malaysia

It has been decided by SPAD, the HSR Malaysia route will be along the coastal area. Malaysia’s geology comprises a wide range of rock types from the sands and silts of the coastal plains to the granite of the Main Range. Geologists group the rocks according to their type, age and environmental deposition. The most widely used unit for geology reference is based on their formation and each type is given its own geographical name. In Peninsular Malaysia, the geology ranges from Cambrian to the Quartenary, that is from 570 million years to about 10,000 years ago, as shown in Figure 6. In Figure 7, the proposed HSR route starting from Kuala Lumpur will pass through a carboniferous area, which prominently consists of limestone. The route then will cross granite in the Seremban area. Towards the south, the alignment will pass through the limestone and sandstone area. The HSR route from Melaka to Nusajaya lies on the coastal area matching with the geology profile of marine and continental deposits. Mostly, the soil conditions are in the form of clay, silt and peat.

According to observations of the IPCC Working Group 1 Summary for Policymakers (SPM) of the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report, the evidence for rapid climate change as noted below is compelling:

- Global temperature rise
- Sea level rise
- Warming oceans
- Shrinking ice sheets
- Declining Arctic sea ice
- Glacial retreat
- Extreme events
- Ocean acidification
- Decreased snow cover

Climate Change and Effects to Railway Infrastructure

Extreme weather events have occurred frequently in Malaysia in the past decade. The most devastating natural disasters experienced in Malaysia are floods and landslides.

1) Floods

The destructive flood in the southern peninsular of Malaysia which occurred back to back in December 2006 and January 2007 are linked to Typhoon Utor. The massive flood in Kota Tinggi, Johor started when the Northeast monsoon brought heavy rain through a series of storms. The series of floods were unusual as the 2006 average rainfall return period was 50 years of return period, while 2007 had more than 100 years of
In Peninsular Malaysia, the geology ranges from Cambrian to the Quaternary, that is from 570 million years to about 10,000 years ago.
Figure 7: Geological Map at HSR Malaysia route

<table>
<thead>
<tr>
<th>QUATERNARY</th>
<th>Marine and continental deposits; clay, silt, sand, peat with minor gravel. Basal of Early Pleistocene age in the Kuantan area.</th>
</tr>
</thead>
<tbody>
<tr>
<td>TERTIARY</td>
<td>Isolated continental basin deposits of late Tertiary age, shale sandstone, conglomerate and minor coal seams. Volcanics in the Sepatam area.</td>
</tr>
<tr>
<td>JURASSIC-CRETACEOUS</td>
<td>Continental deposits of thick, cross-bedded sandstone with subordinate conglomerate and shale/mudstone. Volcanics are locally present.</td>
</tr>
<tr>
<td>TRIASSIC</td>
<td>Interbedded sandstone, siltstone and shale; widespread volcanics, mainly rhyolitic to dacitic composition in Central Peninsula. Limestone prominent in lower part of the succession. Conglomerate and chert are locally prominent.</td>
</tr>
<tr>
<td>PERMIAN</td>
<td>Phyllite, slate and shale with subordinate sandstone and marl. Prominent development of limestone throughout the succession. Volcanics, mainly rhyolitic to andesitic in composition are widespread.</td>
</tr>
<tr>
<td>CARBONIFEROUS</td>
<td>Phyllite, slate, shale and sandstone; argillaceous rocks are commonly carbonaceous, Locally prominent development of limestone. Volcanics of acid to intermediate composition are locally present.</td>
</tr>
<tr>
<td>DEVONIAN</td>
<td>Phyllite, chert and slate; limestone and sandstone are locally prominent. Some interbeds of conglomerate, chert and rare volcanics.</td>
</tr>
<tr>
<td>CENOZOIC-SEMIJURASSIC</td>
<td>Schist, phyllite, slate and limestone. Minor intercalations of sandstone and volcanics.</td>
</tr>
<tr>
<td>CAMBIAN</td>
<td>Sandstone with subordinate siltstone, shale and minor conglomerate.</td>
</tr>
<tr>
<td>PERMIAN-JURASSIC</td>
<td>Intrusive rocks, mainly granite with minor granodiorite.</td>
</tr>
</tbody>
</table>


return period. Local weather changes are among the natural causes that triggered the flash flood. ii) Landslide

Asia suffers more landslides compared to other world regions due to climate. According to United Nations University, among natural disasters, landslides are the seventh ranked killer, after windstorms, floods, droughts, earthquakes, volcanos and extreme temperatures. An average of 940 people were killed annually by landslides in the decade 1993 to 2002, and most of these victims were from Asia. There are many factors which can trigger landslides including changes of slope geometry, changes of water level, rainfall intensity, and changes in loading. However, the major cause of landslides in Malaysia is high precipitation.

Figure 8 shows that after a rockfall due to landslide, vehicles can still swerve and go around the debris. Trains do not have this option, even if a small landslide occurs on the railway line. This brings greater risk to the trains and passengers. It is important for the infrastructure manager to design the slope and track embankment with the consideration of extreme rainfall due to climate change.

A study from the UK demonstrates the disruption caused by the impact of weather on railway lines. The wettest winter on record in England and Wales (2013-2014) caused widespread and severe consequences including flooding and disruption to road transport in the Somerset Levels. It also caused the destruction of the South Devon Railway sea wall at Dawlish (refer to Figure 9), severing rail access to and from the counties of Cornwall and Devon and the rest of the country.

There are many consequences to the railway infrastructure due to hot and dry weather and the obvious example is the risk of buckling. According to Network Rail, the definition of buckling is the extent of track deformation constituting a reportable buckle is that which would render the line unfit for the passage of trains at line speed and/or necessitates emergency remedial work under the cover of either a temporary restriction of speed or closure of the line. Buckling is very treacherous as it could cause derailment to the train and end up disruption of railway operation service. Figure 10 shows a Singapore bound train derailed on January 26, 2013 due to rail buckling. The wagons landed on their sides and trapped the worker and injured five passengers. The train service to the southern part of Malaysia was disrupted for several days due to the difficulties of rescuers to reach the remote area where the incident happened.

Infrastructure Adaptation to Climate Change

Malaysia has conducted several studies on climate change scenarios through the Malaysian Meteorological Department and the Ministry
### Planning Component

<table>
<thead>
<tr>
<th>Planning Component</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Critical weather events</td>
<td>Knowledge and understanding of impact on HSR Malaysia</td>
</tr>
<tr>
<td>Critical components of HSR Malaysia</td>
<td>Knowledge and understanding of vulnerability to critical weather events</td>
</tr>
<tr>
<td>Prediction of climate change impact</td>
<td>Methodology for predicting the impact of specific critical weather events on components of the HSR Malaysia</td>
</tr>
<tr>
<td>Development of adaptation options</td>
<td>Permits evaluation of different adaptation policies</td>
</tr>
<tr>
<td>Design standards</td>
<td>Identification of changes to design standards to mitigate the impact of climate change</td>
</tr>
<tr>
<td>Management policy</td>
<td>Identification of changes to management policy to mitigate the impacts of climate change</td>
</tr>
</tbody>
</table>

**Table 1: Proposed planning process for climate change adaption for HSR Malaysia**

<table>
<thead>
<tr>
<th>Climate Impact Group</th>
<th>Risks</th>
<th>Safety Impact</th>
<th>Performance Impact</th>
<th>Likely Negative Impact from Climate Change</th>
<th>Long or Short Term</th>
<th>Adaptation Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea Level Rise</td>
<td>Increased flooding generally</td>
<td>Medium</td>
<td>High</td>
<td>High</td>
<td>Long</td>
<td>Platform level need to cater to sea level rise and drainage design must cater to ARI plus climate change projection.</td>
</tr>
<tr>
<td>Increased Rainfall</td>
<td>Landslide</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Long</td>
<td>Drainage design must cater to ARI plus climate change projection</td>
</tr>
<tr>
<td>Increased Rainfall</td>
<td>Settlement</td>
<td>High</td>
<td>High</td>
<td>Low</td>
<td>Long</td>
<td>Need to monitor the ground movement and the relation with rainfall intensity especially at the karst area in Kuala Lumpur.</td>
</tr>
<tr>
<td>Heat</td>
<td>Track buckling</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Long</td>
<td>Need to study on rail design resilient to high temperature or provide watchmen</td>
</tr>
</tbody>
</table>

**Table 2: Overview risks of HSR Malaysia**
of Science, Technology and Innovation and several universities. However, there were only a few studies on the threat of climate change to infrastructure particularly in the railway industry. Research conducted by universities in Malaysia centred on the climate change impact on agriculture.

The Climate Change Act 2008 is an Act of the Parliament in the United Kingdom by which statutory authorities, such as Network Rail, are required to comply with formal reporting requirements in respect of climate change adaptation. According to Lane and Dora, in order to undertake the required reporting process, it is firstly necessary to identify the key activities that are required, to develop a reliable method for the prediction of climate change impact as shown in Table 1.

In this case, Malaysia HSR could adopt this planning process and perhaps this policy can be the guidance to the other rail operators such as KTM and Rapid KL. The assessment on the risks and consequences of the critical weather events to HSR Malaysia and possible adaptation measures is thus shown in Table 2.

Concluding Remarks

The Paris Agreement in late 2015 strengthens the collaborative work on global warming reduction. As climate change is real and unequivocal, Malaysia is required to assess the risks of climate change especially to railway operation. There is a lack of studies on the effects of climate change to the Malaysian railway operation and as well to railway infrastructures. Now that Malaysia is planning to build a new HSR, mitigation and adaption measures to the risk of climate change are a must to ensure that we can achieve and deliver:

- A safe railway
- A highly reliable railway
- Increased capacity
- Value for money
- A predict and prevent ethos

Such measures can be integrated into the design and preparation stages so that the infrastructure resilience is built in, improving public safety and reliability.

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REFERENCE


