A Preliminary Risk Identification Framework for Indonesian Railway Ballasted Track

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Railway ballasted track in particular is designed and built to ensure its proper function which is relied on the ability of ballast layers (ballast and subballast) to withstand the train loads, and transfer those into subgrade with relatively uniform response. However, often in practices, the track infrastructures might be facing uncertainties related to some related factors such as ageing, excessive deterioration, increasing train load and speed, environmental damaging effects (i.e. natural hazards). In Indonesia, most of railway ballasted track infrastructures condition which were built in Dutch colonial period are ageing and its behaviour under the current condition are not well understood. Therefore, a risk-based approach using the source-pathway-receptor model can be used to develop preliminary risk identification framework. Thereafter, the railway practitioners and decision makers as a proactive diagnose tool for identify the potential risks. Hence, a better understanding and further assessment of railway track risks can be performed appropriately.

Keywords : railway ballasted track, uncertainties, risk identification, sources-pathway-receptors

1. Introduction

The proper railway infrastructures in Indonesia are needed to deliver an appropriate and sustain performance to rail users (i.e. passengers, freight), particularly the performance of ballasted track which has a vital role in the whole railway track support system. Railway ballasted track, in particular, is designed and built to ensure its proper function which is relied on the ability of ballast layers (ballast and subballast) to withstand the train loads, and transfer those into subgrade with a relatively uniform response.

In Indonesia, despite the total number of passengers and freight tonnages in 2010 only recorded as 7% and 0.6% of public transportation users respectively. These are predicted to increase significantly over the next two decades which are targeted to reach between 11-13 % and 15-17% for passengers and freight users respectively (Indonesian Ministry of Transport, 2011). However, the targets are facing uncertainties lead to potential risks events (i.e., track disruption, failure, natural hazard) due particular uncertainties such as ageing railway infrastructure, excessive deterioration, inadequate track maintenance, increasing train load and speed, environmental damaging effects (i.e. natural hazards)

As mention above, the various aspects can contribute to the potential risk events. In Indonesia, much of railway tracks are built in Dutch colonial period (before Indonesian independence in August 1945). Therefore, most of the current ballasted track performance are susceptible decreased due to deterioration associated with ageing infrastructure (more than 100 years lifetime) and exacerbated with inadequate maintenance and excessive degradation of the railway asset. When the increasing load, speed and environmental damaging effects are implied on the existing track support system, it can be performed poorly and resulting in some adverse impacts to rail users.

In term of addressing the potential risks into current condition, a risk-based identification approach can be used for this purpose appropriately. There are various approaches for identifying risk, which have been widely used in research and practice, one of those is sources-pathway-receptors approach which has been utilised in the UK for the flood risk. This is aiming to address the risk by its causes which are represented by "sources", "pathway" represent the mechanisms by which it would cause harm and "receptors" are associated with the people, property and ecosystem which can be affected by the risk event (McBain, 2010). In this paper, the above-mentioned approach for risk identification is treated. Moreover, the case study on Jakarta flood risk is provided to validate the applicabiity of the approach to the current condition.

2. The Potential Risks of Indonesian Railway Ballasted Track towards Natural Hazards

As a developing country with historical disaster events (i.e. flooding, landslide, volcanic eruption, earthquake and tsunami), Indonesia is facing the potential risk associated with natural hazards (Alcántara-Ayala, 2002). These can potentially affect the current railway ballasted tracks which are located at the prone region throughout Indonesia. Studies have been developed for addressing the potential risks of railway infrastructure. These including flood, landslides, tsunamis, earthquake (McBain et al., 2010; Jaiswal and Westen, 2013; Palin et al., 2013; Pareschi et al., 2000; Polemio and Lollino, 2011; Koseki et al., 2012). Thus, Table 2.1 shows studies across the world region subject to risk associated with the environmental aspect of the railway infrastructure and its related approaches to be utilised.

Table 2.1 Risk-based identification approach in various countries associate with natural hazards.

No	Risk associate with natural hazards	Country	Risk Identification Approach	Author
1	Flooding	UK	Sources-pathway-receptors	McBain *et al.*, 2010
2	Landslide	India	Quantitative risk infomation using historical and derived data	Jaiswal and Westen, 2013
3	High temperature	UK	Regional Climate Model (RCM) and railway industry knwledge	*Palin et al.*, 2013
4	Volcanic eruption	Italy	Geographical Information Systems (GIS), linked with remote sensing technology and telecommunications/ warning systems,	Pareschi *et al.*, 2000
5	Flooding and seepage	Italy	The historical data analysis of flood damages at the watershed scale;	Polemio and Lollino, 2011
6	Earthquake and Tsunami	Japan	Statistics compilation for earthquake and tsunamai-induced damage	Koseki *et al.*, 2012

To be dealt with the various disaster event, a risk-based identification framework is needed to rely on the particular risk event and its causal factors and the further impact to people, property, and ecosystem.

3. Preliminary Risk Identification Framework for Indonesian Railway Ballasted Track Using Sources-Pathway-Receptors Approach

In line with above sections, a proper risk identification framework is of particular importance to be obtained and coped with various uncertainties in Indonesian railway ballasted track. However, consider the complexity of the systems with a lack of historical data, in this paper, the preliminary framework is proposed as the first step of a robust risk identification framework development. Table 3.1 shows the example of this approach for The UK critical infrastructure under flooding event. Otherwise, Table 3.2 shows the utilisation of the preliminary risk identification framework for Indonesian railway ballasted track under uncertainties.

Table 3.1 Sources-pathway-receptors for the UK critical infrastructure under flooding event

Sources	Pathway	Receptors
• Rainfall • River flows • Artificial drainage systems • Extreme sea levels • Wind-generated waves • Tidal-storm surges • Tsunamis • Lakes/reservoirs • Canals • Groundwater • Mines/quarries	• Overtopping and failure of flood defences • Breeching of natural or manmade coastal defences • Failure of flood defence components, eg barriers and gate • Inudation of floodplains • Inadequate drainage	• People • Domestic and commercial property • Emergency services installations • Infrastructure • Ecosystems

Table 3.2 Sources-pathway-receptors for the Indonesian ballasted track under various uncertainties

Sources	Pathway	Receptors
▪ Aging railway infrastructure ▪ Insufficiently and inadequately maintained tracks ▪ Increasing train load and speed ▪ Environmental damaging effects ✓Extreme events (e.g. flooding and extreme heat)	▪ Climate change, climate extremes, geo-hazards, excessive deterioration of railway track-bed lead to substantial track failures and their impacts (i.e. speed restriction, unplanned maintenance, delay times, additional passengers and freight costs)	▪ Train passengers ▪ Freight consumers ▪ Rail infrastructure operator : ✓ Railway track subgrade ✓ Railway track earthworks ▪ Train operator : ✓ Rolling stock (train) life times ▪ Ecosystems

4. Case Study: Risk Identification of Railway Ballasted Track Associated with Flood Event in Jakarta Indonesia

4.1 Background

Flood event in Jakarta and its causal factors has been reported in some documents (Caljouw et al., 2005; Gaillard et al., 2008, Gierveld and Jan van der Burg,2012). These factors are identified as rising sea level, land subsidence, increased rainfall, lack of open space, non-functioning drainage and canal systems, insufficient upstream river and water management (Gierveld and Jan van der Burg,2012). When the flood event occurs in Jakarta, which is known as Indonesian capital city with many rail infrastructure and users (Indonesian Ministry of Transport, 2013), the impacts might be severe or catastrophic. The consequences of flood risk are shown on figure 1,2,3 (The age, 2007; The Jakarta Post, 2013). Therefore a case study in Jakarta is important to examine how the flood risk affects the railway ballast track which can be lead to adverse impacts on rail infrastructure asset and the rail users.

Figure 1. Passengers evacuation process (The age, 2007)

Figure 2. Overtopping and failure of flood defences (The Jakarta Post, 2013)

Figure 3. Ballast layers and subgrade washed out (The Jakarta post, 2013)

4.2 Area of Study

The study was carried out along a transportation corridor of 664 km2 area encompassing a 170.2 -km-long section of a railway ballasted track as shown in figure 4 (Indonesian Ministry of Transport, 2013)

LINE	KORIDOR	PANJANG (KM)
Central (Tengah)	Jakarta Kota – Manggarai	9,7
Bogor	Manggarai – Bogor	44.9
Bekasi	Jatinegara – Bekasi	14.6
Lintas Timur	Jakarta Kota – Jatinegara (Via Ps Senen)	11.4
Lintas Barat	Jakarta Kota – Jatinegara (Via Tanah Abang)	15.6
Serpong	Tanah Abang – Serpong	23.2
Tangerang	Duri – Tangerang	19.3
Tanjung Priok	Jakarta Kota – TJ. Priok	9.0
	TJ. Priok – Kemayoran	9.5
Nambo	Citayam – Nambo	13.0
Total		170.2

Figure 4. Current Greater Jakarta Railway Ballasted Track Network (Indonesian Ministry of Transport, 2013)

4.3 Preliminary Risk Identification Framework Using Sources-Pathway-Receptors Approach

The performed case study on Jakarta railway ballasted track along 170. 2 km as shown in Figure 4. Data was collected from railway master plan for greater Jakarta 2020 (Indonesian Ministry of Transport, 2013), and other documents associate with Jakarta flood risk in decades (Caljouw et al., 2005; Gaillard et al., 2008, Gierveld and Jan van der Burg,2012). The study was performed on the railway ballasted track using sources-pathway-receptors.

Table 4.1 shows the framework to identify the causal factor of risk (column 1, sources), failure scenario (column 2, pathway), and potential receptors (column 3, receptors). Column 1 indicates the causal factor associated with environmental damaging effects (i.e. rising sea level, land subsidence); urban planning (i.e. lack of open space); urban and railway drainage systems (i.e. non-functioning drainage and canal systems), water resource management (insufficient upstream river and water management).

In line with column 1, column 2 consists the potential failure mechanisms on railway ballasted when flood risk occurs. First, failure on flood defence and earthworks (i.e. flood protection, embankment, cutting slope). Second, failure on track support system (i.e.,.water retain in ballast layers). Third, defective railway ballasted track drainage system due to blockage on the drainage arrangement (i.e.,.blockage of the drainage systems lead to subgrade softening and excessive settlement.

As mention above, column 1 and column 2 are performed to identify the sources of the Jakarta flood risk, and its potential failure scenario (pathway). On the other hand, column three rely with the receptors which consist various parties such as train passengers, freight consumers, rail infrastructure owner and operator, train operator, property owner and people along the railway ballasted track, ecosystems.

Table 4.1 Sources-pathway-receptors for the Greater Jakarta railway ballasted track towards flood risk

Sources	Pathway	Receptors
▪ Rising sea level ▪ Land subsidence ▪ Increased rainfall ▪ Lack of open space ▪ Non-functioning drainage and canal systems ▪ Insufficient upstream river and water management	▪ Overtopping and failure of flood defence ▪ Failure of railway earthworks (embankment, cutting slope) ▪ Water retain in ballast layers lead to wet bed condition ▪ Blockage of the drainage systems lead to subgrade softening and excessive settlement	▪ Train passengers ▪ Freight consumers ▪ Rail infrastructure owner (Indonesian Ministry of Transport) ▪ Rail infrastucture operator ▪ Train operator ▪ Property owner along the disrupted track. ▪ People who live at the surrounding railway track ▪ Ecosystems

5. Conclusion

This paper described the utilisation of source-pathway-receptors as a preliminary risk identification framework. Identification was performed using the case study on railway ballasted infrastructure towards flood risk (i.e., Jakarta flood event). The case study showed that the proposed framework can be used to determine the risk causal factors (sources) systematically. These are associated with environmental, urban planning, urban and railway drainage systems, water resource management in the surrounding catchment areas. Moreover, the failure pathway and receptors described the potential failure scenarios (i.e., failure of flood defence, earthworks and cutting slope, track support system(ballast layers), track drainage system) and affected parties in a logical manner. In conclusion, this framework is useful as a predictive tool for identifying the potential risk on railway ballasted track quantitatively.

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