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Building Resilient Societies: Towards a Safe, Climate Adaptive and Disaster Resilient Transport System for Asia

(Background Paper for Plenary Session 1 of the Programme)

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This background paper has been prepared by Madan B. Regmi and Trang Luu, for the Ninth Regional EST Forum in Asia. The views expressed herein are those of the authors only and do not necessarily reflect the views of the United Nations.

Building Resilient Societies: Towards a Safe, Climate Adaptive and Disaster Resilient Transport System for Asia[1]

1. INTRODUCTION

Transport plays an essential role in facilitating economic growth and social development. Transport provides essential link to communities and societies, villages, cities and in larger context connects countries and regions. It plays important role in maintaining the delivery of goods and services as well as providing access to daily necessities such as education, healthcare and logistics. However the region's transport system to prone to impacts of climate change and natural disasters as well as it produces externalities such as congestion, traffic accidents, emissions, and consumes fossil fuels. These are inevitable consequences of transport operation. Therefore, there is growing arguments that transportation system should be safe, sustainable and more resilient.

The economic growth coupled with rural-urban migration and rapid urbanization has generated tremendous pressure on the transport. Further, unbalanced growth across different parts of society together with large population migrating to cities has challenged transportation capacities to meet the need of these urban dwellers.

Increased surface temperature, sea level rise, and enhanced intensity of extreme weather events have already threatened transport infrastructure and its resilience (Karagyozov 2012, Barami 2014, Eichhorst 2009, Jaroszweski 2010). Given the importance of the transport sector, it is undeniable that any disruption of mobility would seriously impact economic growth and social development. Transport is also a key contributor to the global warming as the sector shares a large portion of total energy consumption worldwide (IEA 2013, Marcotullio 2007) and operation of vehicles also releases a great amount of GHG emissions into the atmosphere. This two-way interaction in which transport plays as both the giver and taker of global warming creates challenges but also offers opportunity to be greener and resilient and adapt to climate change.

Within the context of rapid urbanization and the changing climate, it is essential for societies to be able to cope with upcoming uncertainties and simultaneously manage existing challenges. For instance, over-crowded cities lacking the capacity to serve the growing population would have more traffic accidents because there are more users on the road. Such problem gets worse when urban planning fails to manage living space, taking long time for its residents to commute from one point to the other. Furthermore, impacts of climate change lead to more negative consequences as they exacerbate infrastructure quality and disrupt transportation mobility. This problem is hence a multi-faceted issue in which tackling only one angle of the complex at a time has proven to be costly and ineffective. Building resilient transport is therefore an

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interdisciplinary solution that can create safe, climate adaptive and disaster resilient transport systems that help solve these problems. The recently adopted SDGs include goals and targets related to transport. Countries and cities should now focus their attention to achieve those by 2030 by adopting and implementing innovative policies.

Acknowledging the urgent threat of climate change and the enhanced intensity of natural disasters, transport policymakers need to consider the importance of transport resilience. Resilience framework initially comes from an ecological perspective but then has been gradually expanded into other social dimensions. In particular, the Victoria Transport Institute in Canada defines resiliency as a system's ability to accommodate variable and unexpected conditions without catastrophic failures, or in other words, the capacity to absorb shocks gracefully (Foster, 1993). The European Roadmap Climate Resilient Road Transport envisages a resilient transport network that allows key corridors to be available to all users in all weather conditions (ERTRA, 2011). A resilient transport system hence would ensure countries and communities to have safe and reliable mobility under uncertain risks induced by climate change and natural disasters.

In this context, this background paper discusses current issues and challenges facing transport sector in the region and aims to collate cases and best practice of developing safer, more climate adaptive and disaster resilient transport system in Asia and the Pacific. Following this introduction, section 2 covers transport safety. Section 3 and 4 outline climate change adaptation and disaster resiliency respectively. Section 5 sums up the main challenges and suggest recommendations for policymakers while the conclusions are outlined in section 6.

2. SAFE TRANSPORT

2.1 Overview of road safety in Asia and the Pacific

Road traffic injuries are ranked as the eighth leading cause of death globally by the Global Status Report in 2013 and as projected by 2030; it would become the fifth, higher than lung cancer and HIV/AIDS if no serious actions will be taken (WHO, 2013). In the Asia-Pacific region, road traffic death rate per 100,000 population is 18.62, higher than the world average of 18.04. In 2010, there were more than 777,000 fatalities from traffic crashes in the region, which is more than 62% of the world's total 1.24 million. Furthermore, about 90 per cent of road traffic deaths happened in low-income and middle-income countries in which the poor has to bear the greater costs. Road safety is therefore not only a problem of public health but also an issue of social exclusiveness that hindrances economic growth and social development. Although urbanization and economic growth worsen traffic situation in many developing countries, some middle-income countries can manage to have safe mobility and raise incentive for shared public transportation.

Figure 1 presents estimated road traffic death rate per 100,000 population coupled with national GDP for some countries in Asia. It can be inferred from the figure that high income countries such as Brunei Darussalam, Japan and Singapore have relatively low rates of road fatalities. On the other hand, lower income countries such as Thailand, Viet Nam and Malaysia have higher rates. In particular, Thailand has the second highest road traffic death rate in the world at 38.1, only after the Dominican Republic at 41.7 (WHO, 2013). However, the figure also shows that

GDP per capita is not the sole factor that accounts for road fatalities. For instance, the Philippines, a low-middle income economy manages to have road fatality rate of less than 10. Road safety therefore depends on a variety of other factors such as government's regulations, policy enforcement, public awareness, behavior changes, improved transport infrastructure, and in time post-accident responses. Cooperation of transportation and other sectors such as health, education and communication technology is essential in improving traffic conditions. Fatalities from road traffic accidents rose quickly in high-income countries during the 1950s and 1960s when their economy were expanding. Until the 1970s, road accidents were still a big challenge. However, since 1980s-1990s, injuries have been reduced by as much as 50 per cent in many countries despite continuing economic growth (UN-Habitat, 2011). Such improvement has been due to a shift from focusing only on behavior change to integrating safety system implementation as well as good traffic management.

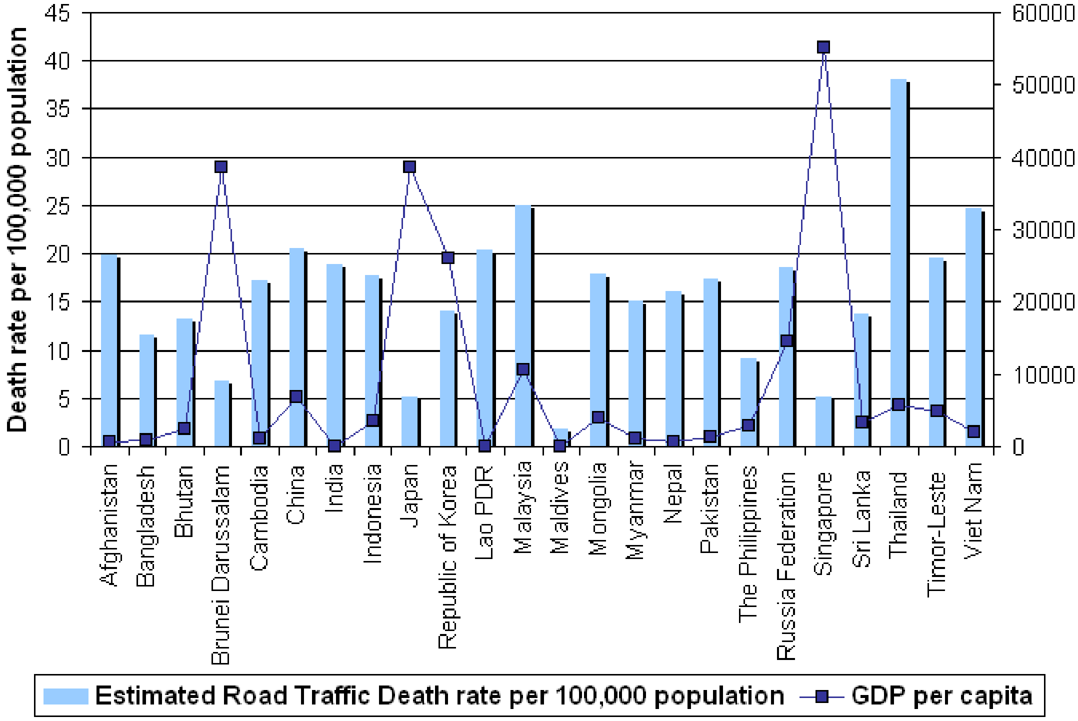

Figure 1: Estimated Road Traffic Death rate per 100,000 population Sources: WHO (2013); World Bank (2015)

2.2 Vulnerable road users

Excessive dependence on motorized vehicles in large cities makes traveling unsafe; especially for vulnerable road users[2] and they are at greater risks than vehicle occupants and usually bear the greatest burden of road injuries (WHO, 2004). Vulnerable road users accounts for more than 55% of total deaths in the Asia and Pacific region[3]. Especially in many Asian developing cities, motorcycles dominate the streets in the absence of segregated lanes for trucks, buses, cars, two-three wheelers and bicycles. This makes traveling more dangerous as vulnerable road users

[2] Includes pedestrians, cyclists and motorcyclists
[3] WHO, 2013

expose to higher risks incurred by more heavy vehicles, increasing the probability of traffic crashes. For example in Hanoi, there is the lack of separation line between slow moving non-motorized vehicles and fast moving motorize vehicles as well as insufficient amount of paved roads or footpath for pedestrians. Box 1 examines this issue and policy that has been taken in Hanoi, Viet Nam's capital city.

Box 1: Hanoi's mixed traffic predominated by motorized vehicles

Figure 2: Mixed Traffic in Viet Nam (Source: Nguyen Huu Kham/Reuters, 2015)

Viet Nam has been known for its high occurrence of traffic accidents. Particularly in the capital Hanoi, rates of fatalities, injuries and congestions are among the highest. One of the main reasons for this is due to the city's mixed traffic and the predominance of motorized vehicles such as motorbikes, cars, trucks and non-motorized vehicles such as bikes and cycle rickshaws sharing the same lane. In addition, sufficient paved roads for pedestrians are not available, making it extremely unsafe for VRUs and discouraging them from using public transportation.

Municipal policymakers therefore have decided to implement segregated lanes in some main routes to stabilize traffic flow. The new policy has reduced traffic vehicle lane changing percentages, increased road capacities, and lessened road crashes. Stricter plans to build hard lane separation have also been in effect, encouraging road users to obey road traffic rules and making traffic flow more uniformly in the street of Hanoi.

In some developing countries such as India, Indonesia, Thailand and Viet Nam, it is common for people to use motorcycles even for intercity trips of distances over 200 km. This may be because of the unavailability of good quality transport services. Or in some cases, in the eyes of some middle class urban residents, for whom cars may still be unaffordable, the motorcycle is seen as a step up in the ladder of private personal mobility.

On another note, a significant proportion of Asia's population still depends largely on walking and bicycling. For many cities in Asia and the Pacific, there are still relatively high modal share of walking and cycling such as 46% in Guangzhou and 42% in Bangalore. As in the case for many urban poor, non-motorized transport is the only accessible and affordable mobility option. In particular, more than one in three road traffic deaths in low-and middle-income countries are among pedestrians and cyclists (WHO, 2004), excluding them from participating in economic and social opportunities, which further trapping them in the circle of poverty.

Furthermore, developing countries in Asia and the Pacific have been focusing on strategies to enhance economic growth through promoting trade and smoothing supply chains. These include expanding road and transport infrastructure, mostly favor motorized vehicles over people, which threaten the safety and rights of VRUs and discourage them from utilizing more people and environment friendly transportation such as walking, cycling or taking public transportation. Surveys carried out by Clean Air Asia asked 4,644 pedestrians across thirteen cities in Asia to access their incentive while using non-motorized transportation. The report finds out that if the walking environment is not improved, 81% said that they will shift to other modes of transportation when they can afford to, including 25% to cars and 13% to two-wheelers (Leather, et al., 2011). This makes building safe and people friendly transport a co-benefit strategy as it can reduce the use of private vehicle and at the same time improve quality of life.

2.3 Urban public transportation in Asia and the Pacific

The Asia-Pacific region is home to more than two billion city residents, representing 55 per cent of the world's urban population – a figure that will rise to 64 per cent in 2050 (UNESCAP 2014b). Seven out of the world's ten most populous cities are located in the region. With rapid growth of private vehicle ownership has led to worsening traffic, congestion, increasing fossil fuel consumption, traffic accidents, GHG emissions and air pollution, thus creating negative externalities on the economy and lowering quality of life for its residents. In fact, transport is considered the only sector that is worsening as income rises. While sanitation, health, education and employment tend to improve as the economy grows, traffic fatalities, injuries and congestion tend to get worse (UN-Habitat 2011).

Moreover, the proportion of urban residents to be living in slums is estimated to be 28 per cent for East Asia, 31 per cent for South-East Asia and 35 per cent for South Asia (UN-Habitat 2012). With such large numbers of the poor, governments must strive to provide not only environmentally sustainable transport, but also socially inclusive transport systems which meet the mobility needs of all people. Much attention has been given to addressing urban mobility in large cities while the majority of the Asia and Pacific region's urban population lives in rapidly growing small and medium-sized cities and towns. Indeed, more than half of the region's urban residents live in smaller cities with fewer than 500,000 people (UNESCAP, 2014b). These secondary and medium-sized cities will follow unsustainable growth patterns if more effective strategies for integrated land use and transportation planning are not developed (UNESCAP, 2012). Given their early stages of development, these cities offer the best opportunities to plan and implement innovative transport policies and strategies.

The most optimal solution to road safety and traffic congestion is to shift mobility towards public transport system thereby reducing the need to use private vehicle. Several Asian cities such as Hong Kong Special Administrative Region of China, Seoul, Tokyo and Singapore have well-functioning urban public transport while most other cities are in the process of designing and developing their own systems. In recent years, there have seen an expansion of mass transit options in many Asian cities such as in Bangkok, Jakarta, Kuala Lumpur, Shanghai and Beijing, etc. Among the established mass transit networks, bus rapid transit system (BRT) is popular in

Asia and is significantly cheaper and easier to implement and operate. Currently 38 Asian cities are operating 1,375 km of BRT routes and carrying more than 8.5 million passengers per day.[4]

In many low- and middle-income countries, public transport systems are poorly constructed and are usually overloaded or not running on planned schedule. Besides non-motorized transportation such as walking and cycling, poor households have no other choices but depend largely on over-crowded, unreliable and unsafe public transportation. In this regard, the upgrading of existing public transport systems and the introduction of newer, more efficient systems are urgently needed. Municipal authorities therefore should take into account not only the quantity of public transport such as expanding number of buses and increasing bus stops but also improving the system's quality such as enhancing safety, accessibility, and reliability so that the network can meet the need of all.

2.4 Railway safety

Railway transportation is usually considered safer, more environment friendly and affordable than road transport, covering long distance and serving a large number of passengers. Nevertheless, railway safety is still a pressing issue for some low- and middle-income countries in Asia-Pacific due to low quality infrastructure, loose regulations in addition to poor public awareness. Among the main causalities of railway accidents, unlawful trespassing tops the list. Such accidents occur due to the lack of barricading and fencing, lack of adequate number of pedestrian over-bridges, as well as insufficient number of facilities such as platforms, escalators and elevators at train stations. The second largest group of railway fatalities happen due to level crossings, where roads or footpaths cross railway lines at level, including both manned and unmanned ones (Evans et al, 2013). There is collision risk between trains and road vehicles or pedestrians at intersection if warning signs and alarm system do not work appropriately. Most of the accidents cause injuries or fatalities to road users, road vehicle occupants or pedestrians, and also sometimes staff or passengers on trains. Other causalities of railway accidents are derailment, collusion, on-train fire, bad weather, etc. Given the large amount of passengers served by train services in Asian countries (for example in 2014: 8,397 million passengers per year in India, 7,289 million in Japan, and 1,641 million in the Republic of China- hereafter China) and the variety of railway safety level among countries in the region, knowledge sharing and technical transfers are very essential in improving railway safety for developing countries in the Asia-Pacific region.

India has the fourth longest railway system in the world with more than 64,000 kilometers rail in length, only after the United States, Russian Federation and China, but the Indian railway system has major safety concern. From 2009 to 2014, there were 674 train accidents in India, killing 502 and injuring 1,531 people (Government of India, 2015). According to the same report, of 117 train accidents occurred in India during 2013-2014, 52 accidents were due to derailments while 51 accidents resulted from level crossing.

Given rapid urbanization and pressures from economic growth, rail transportation plays a very important role serving people's commuting need. Investment in improving trains and railway infrastructure and safety should receive priority in addition to raising public awareness of

[4] http://brtdata.org/ (accessed May 2015)

passengers and staff using the system. A safety management system including up-to-date database and rail accident risk analysis should be implemented to help strengthen safety quality of railway transportation.

2.5 Maritime and inland waterway safety

Given the growing globalization that has resulted in the increasing amount of trade in addition to the enormous pressures to reduce GHG emissions from transport sector, the role of maritime and inland waterways has become more and more important. In particular, maritime transport connected with supply chains, provides access to the global market as well as enhances domestic and international mobility. On another note, inland waterways offer strategic passage through congested cities and cross-border transport options. For instance, inland water commuting by boat is one of the main means of transportation within Bangkok Metropolitan area. The system includes Chao Phraya Express crossing Chao Phraya River and Khlong boats sailing along Saen Saeb canal. Both routes connect office hubs, schools, hospitals, residence areas and help passengers avoid traffic congestions during rush hours at affordable prices. As the network of maritime transport and inland waterway traffic increases, safety is becoming a priority for policymakers. This expansion requires governments to catch up with the increasing demands of maritime traffic by improving infrastructure, building capacity for staff, and enforcing regulations to assure safety.

In many countries where navigational rives are available, informal form inland water transport exist. The boats, vessels used for river transportation are conventional and not well maintained, coupled with the poor river port infrastructure. These pose major safety concerns. One of the main issues facing maritime and inland waterway safety is accidents near ports. Even though countries in the Asia-Pacific region depend largely on maritime trade and domestic inland waterways transportation, infrastructure quality still raises big concern. Poor terminal infrastructure of river and sea ports lacking adequate handling equipment worsens transportation reliability and also increases shipping costs. The International Convention for the Safety of Life at Sea (SOLAS) specifies minimum standards required for ships' construction, equipment and operation, compatible with their safety; failing to meet these minimum requirements would increase risks and potentially cause accidents. However, regulations and enforcements have not been strictly implemented, threatening the safety of passengers and staff as well as increasing seaborne and inland waterway risks. This calls for the need to improve safety at sea and inland waterways by enhancing government's enforced regulations, improving infrastructure quality as well as raising public awareness and education on safety.

Use of information and communications technology to enhance efficiency and safety of transport operations is often referred to as an intelligent transport system. The most common use of such systems are in traffic regulation and management, providing real-time travel information to users, assisting route planning, ticketing, toll collection and electronic payments. Authorities and transport operators can consider greater use of appropriate intelligent transport systems to improve the efficiency and safety of urban transport systems. ITS help improve safety on highways by connecting vehicle information, highway conditions and drivers as once accidents occur, ITS help deliver emergency response information. In addition, the system allows better

coordination between public transport modes and the integration of timetables, thereby enhancing the efficiency of operations and services.
Another potential use of information and communications technology is to avoid the need to travel by reducing non-essential trips. This would contribute to traffic demand reduction. For example, citizens can pay municipal and utility bills using online computers from home or local kiosks. Videoconferences and webinars can also help to reduce business travel.

3. CLIMATE ADAPTIVE TRANSPORT

3.1 Overview

The Intergovernmental Panel on Climate Change's Fifth Assessment Report confirms that human influence on the climate system is clear, and recent anthropogenic emissions of GHG are the highest over the last 800,000 years (IPCC, 2013). Recent climate changes have had widespread impacts on human and natural systems, amplifying existing risks such as food security, public health, and social inclusiveness. Indeed, in Asia and the Pacific region, many developing countries are working hard to lift themselves out of poverty, but climate change induced events and natural hazards in turn diminish the outcome of such efforts. On average, floods in Asia and the Pacific developing countries costs from 3 to 5 per cent of their GDP, cancelling out significant efforts having been made toward poverty eradication and social development (UNESCAP, 2014a).

The debate on climate change has shifted from questioning whether climate change exists to discussing how and to what extend countries should mitigate and adapt to its impacts. Given the accelerating frequency and intensity of extreme weather events, such questions have never been more urgent, especially for the Asia-Pacific region. The IPCC's Fifth Assessment Report confirms that Asia experienced the highest number of weather and climate related disasters in the world during 2000-2008 (IPCC, 2013). More critically, many Asian cities are located in coastal areas and are highly vulnerable to increased precipitation, storm surges, cyclones, and sea level rise. In addition, small island developing countries in the Pacific also have been facing increasing amount of disaster events and sea level rise, threatening economic growth and livelihood. Damaged bridges, railways, roads, airports, and other transport infrastructure do not only incur reconstruction costs to transport sector alone but diminish recovering efforts in other sectors as it takes longer time and more money to access affected areas. Since economy depends largely on services provided by transport, the sector plays an important role in achieving sustainable development goals and must get prioritized attention from policymakers, private stakeholders and grassroots communities.

3.2 Impacts of climate change on transport sector

Almost every aspect of life is affected by direct and indirect impacts of the changing climate. Extreme weather events such as storm surges, floods, droughts, changes in precipitations and permafrost conditions as well as sea level rise can affect transport infrastructure and consequently human mobility. Indeed, research has focused extensively on the potentials of climate change mitigation in urban transport but not so much on vulnerability, impacts and adaptations (Hunt and Watkiss, 2011). Assessments of climate change impacts on transport infrastructure and management have been initiated in developed countries (Barami, 2014). However, studies that are specifically applicable to Asia and the Pacific have not yet been fully utilized. Transport infrastructure and management schemes in Asia vary greatly across countries, and climate change impacts on the systems differ within the region. For instance, a study finds that one meter sea level rise would inundate, and hence destroy, 19,000 kilometers of roads in Viet Nam, which is equivalent to 12 per cent of the country's existing road stocks (Chinowsky et al. 2012). The study also shows that rebuilding these damaged roads would cost approximately US $ 2.1 billion. Given the high vulnerability to climate change, it is essential to have common guidelines and databases estimating climate impacts as well as costs on transport infrastructure. Table 1 lists climate events, some of the potential impacts and suggested adaptation measures.

3.3 Impacts of transport sector on climate change

Besides being affected by climate change, transport sector also contributes significantly to GHG. In 2011, transportation accounted for about 26% of the world's energy use and 62% of global oil consumptions (IEA, 2013). In addition, transport shares 22% of global CO_2 emissions, only second to electricity and heat at 42%. It is projected that compared to the 2010 level, global CO_2 emissions from transport are expected to rise by 70 per cent by 2050 and the vast majority of projected increase is expected to come from developing countries in Asia (ADB 2009, IEA 2013). Taking into account the region's economic growth and rapid urbanization, Asia's need for energy during the upcoming decades is enormous. ADB estimates that by 2030 Asia will account for 31% of total worldwide CO_2 emissions related to transport sector while this indicator is 19% in 2006 (ADB 2009).

Within transport sector, rapid GHG emissions and pollution have been resulted largely from road transport, which increased 52% since 1990 and accounted for about three quarters of transport GHG emissions in 2011. In addition, emissions from marine and aviation bunkers grew even faster than from road, at about 80% higher in 2011 than in 1990 (IEA 2013). Figure 3 demonstrates the growth in CO_2 emissions from Transport Sector in 1990 and 2011.

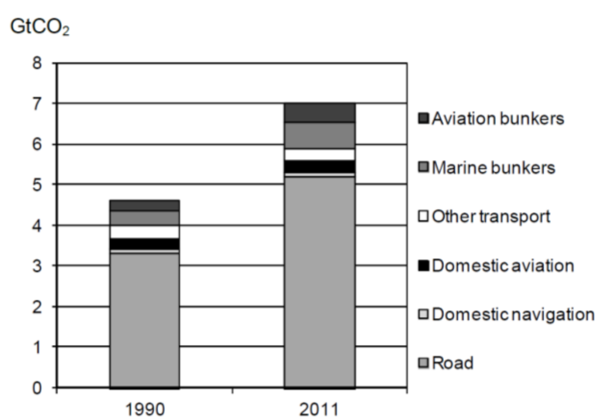

Figure 3: CO2 Emission from Transport (Source: IEA 2013)

Table 1: Impacts of Climate Change on Transport Infrastructure and Adaptation measure

Climate Change Events	Impacts on Transportation and Mobility	Adaptation Options
Increase in number of hot days and heat waves	- Thermal expansion of bridge joints and paved surfaces - Pavement deterioration such as softening, traffic-related rutting, and migration of liquid asphalt, buckling and railway tracks - Rail-track deformities, increased numbers of tire blow-outs - Increased energy costs for transport facility operations - Reduced engine combustion efficiency	-Use stiff bitumen and material to withstand heat -Use tires with low air pressure, tubeless tires
Increased in temperature in very cold areas	- Changes in road subsidence and weakening of bridge supports due to thawing of permafrost - Less dependent on permafrost/ice roads	-Ensure quality of construction and compaction of embankments and fillings
Sea level rise and increases in storm surges	- Damages to highways, roads, underground tunnels, bridges and low-lying infrastructure due to flooding, inundation in coastal areas and coastal erosion - Damage to infrastructure from land subsidence and landslides - Erosion of road base and bridge supports - Decreased expected lifetime of highways due to storm surges - Reduced clearance under bridges - Impacts on supply chain from potential shipping interruptions - Scarcity of available land for transportation services	- Monitor of certain roads that may be submerged - Use suitable materials and proved lateral protections - Raise road level, construct levy bank with drainage/seawall, protect levy bank with mangroves - Increase budget for maintenance and operations - Include additional longitudinal and transverse drainage systems - Replace metal culverts with reinforced concrete - Restrict infrastructure development in vulnerable areas
Increase in intense precipitation events	- Damage to roads, subterranean tunnels, and drainage systems due to flooding, scouring, and increase in soil moisture levels - Damage to roads due to landslides and mudslides - Overloading of drainage systems - Delay traffic, increase subway flooding, poor vision - Increase maintenance costs for roads, utilities and runway and costs for flood control and erosion prevention.	- Reduce the gradients of slopes - Increase size & height of engineering structures -Increase water retention capacity and slow infiltration - Raise embankments and add additional drainage capacity - Increase monitoring of vulnerable roads - Use water capture and storage systems - Enclose materials to protect from flood water
Increases in drought conditions	- Damage to infrastructure due to increased susceptibility to wildfires and mudslides - Shortage of water supply for road maintenance - Poorer quality groundwater	- Use flexible pavement structures - Increase maintenance, water retention capacity - Use matting/erosion control blankets - Select materials with high resistance to dry conditions
Increases of storm intensity	- Increased threat to stability of bridge decks - Increased damage to signs, lighting fixtures, and supports - Reduced off-road maneuver capacity - Increased maintenance costs and increased flood control/erosion prevention measures	- Modify the design of supports and anchorages - Install projection systems such as windbreaks - Plant coastal forests and mangroves

Sources: Adapted from Barami (2014), ADB (2014), IPCC (2014), Regmi and Hanaoka (2011)

3.4 Mitigation and adaptation strategy for transport

It is no longer possible to plan and construct transport systems with a stationary climate. The planning, implementation and management of transport need to take into account the current and projected future climatic changes. Since transport sector contributes a large share to GHG emissions, much of the scholarly work on transportation and climate change has been mainly focused on mitigation (Oswald 2009). However, actions to combat climate changes should no longer be considered for "our grandchildren's future" anymore but an urgent action of our time. Increased temperature, change in precipitation patterns and extreme weather events can be observed in most part of Asia-Pacific region, costing us millions of lives and billions of dollars every year. Being able to adapt to the changing climate and to mitigate the consequences of such disaster events can help countries, especially developing ones reduce risks and become more resilient to natural shocks.

Energy security in Transport

One of the options being debated for energy security and emission reduction from the transport sector is use of electric vehicles. Fuel efficient electric and hybrid cars are emerging due to advances in vehicle technology. However, their sustainability depends on the source of electricity used for charging. If the electricity is generated from coal burning, electric vehicles can be more polluting than petroleum-fuelled vehicles. Therefore more technological advancement is necessary to develop sustainable energy generation, vehicle technology and commercial availability of electric vehicles in market especially concerning range, performance, charging infrastructure and charging time. Some Asian countries such as Bhutan, Laos and Nepal have started using some forms of electric vehicle though in limited extent. Lao PDR is experimenting using electric public buses in Luang Prabang, Nepal is using battery operated para-transit Tempo (three wheelers) and Bhutan has just initiated promotion of electric cars in Thimphu. These three countries are of significance here as these countries have potential to develop green energy from hydropower. This looks ambitious even though Asia is net exporter of energy, very few countries meet their own energy demand and currently 628 million people are without electricity. Discussions are ongoing at regional level that there is potential for developing transboundary transmission lines in Asia- this would help countries in meeting their energy demand and for country having excess energy to trade. Alternative forms of fuels, such as biofuels, are also being developed, although they are not available on the market in abundant quantities.

The case of storm water management in Kuala Lumpur provides useful example of adaption strategy in transport and flood control. Kuala Lumpur is one of the most crowded cities in South East Asia. The capital faces traffic congestion issues as well as flash floods during monsoon season. In order to solve these problems, in 2007 the Malaysian Government launched the Stormwater Management and Road Tunnel (SMART), a 9.7 km-long storm drainage and road structure project. The drain functions in three operational modes, allowing large volume of flood water to be diverted from the city's financial district to a storage reservoir. Under normal conditions with no storm, no flood water is diverted into the system. When the second mode is activated, flood water is diverted into the bypass tunnel underneath the motorway tunnel while the motorway section is still open to traffic. During the third mode, the motorway is closed to all traffic. After the automated water-tight gates open and allow flood water to pass through, the motorway is reopened to traffic, usually within 48 hours. Within the first three years in operation, SMART project has successfully averted at least seven flash floods and solved traffic congestions, saving hundreds of millions in potential losses.

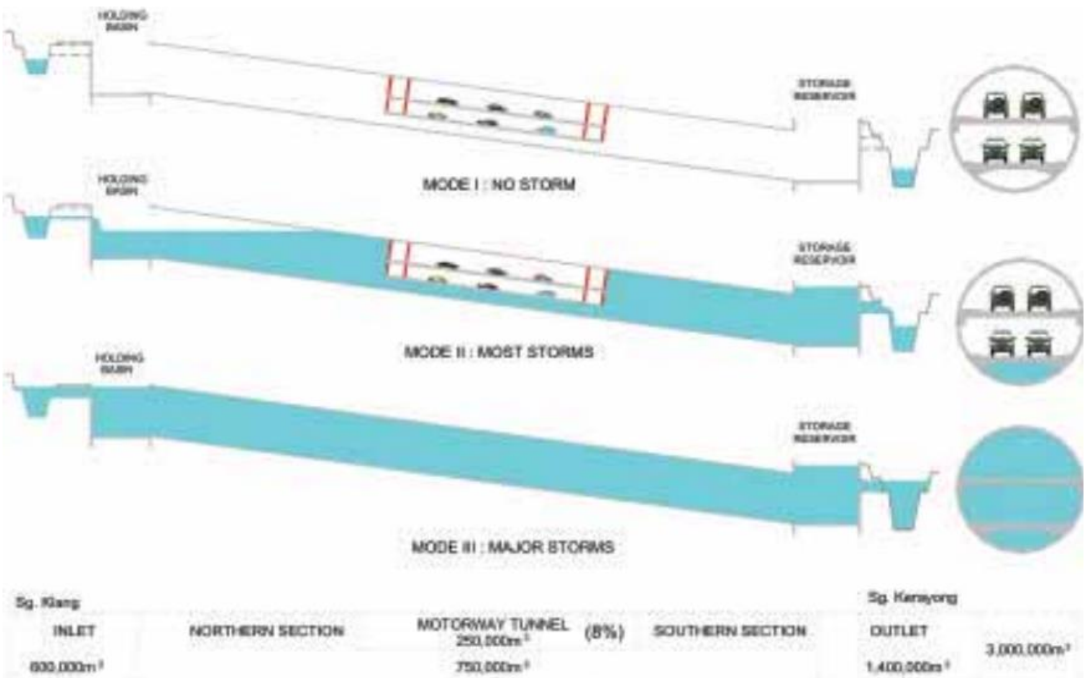

Figure 4: SMART Tunnel, Kuala Lumpur (Source: Darby A, 2007)

The public transit information system in Metro Manila provides information on bus and rail routes, location of rail and bus stops, operating hours, as well as fare schedule. This open platform allows independent developers to create applications that support the use of these data to benefit road users to avoid traffic, to inform about weather conditions, and to seek for alternative routes when there are floods or other natural disasters. Such initiative has shown the feasibility of ITS in low- and middle- income countries to solve congested traffic and reduce climate change vulnerability.

Furthermore, adaptation should not be just about surviving a disaster but seeking smart solutions to shorten recovery time and bring societies back to normal functioning as quick as possible. Planning for climate change resilience hence involves taking steps to prevent disruption effects, prepare to withstand damages, and rapidly recover from negative consequences (Barami 2014). According to the resilience framework designed by Volpe- the U.S. National Transportation Systems Center, a climate resilient infrastructure must have adaptive properties that do not only absorb damages and disruptions but can also learn from climate events and become more resilient. In other words, resilience does not mean automatically bouncing back or simply resuming life as it was before but actually learns, adapts, corrects past errors, self-organizes, and forges new solutions that can minimize climate change impacts (Barami 2014).

It is important to note that both adaptation and mitigation strategies should be integrated collectively in transport planning, investment and implementation. As transport infrastructure quality is still quite low in many developing countries in Asia, successful adaptation strategies will have to do more than just merely adjusting already existing networks but also building new resilient infrastructure. Particularly for some developing countries in the region, half of the roads are unpaved, 30 to 40% of villagers are without all-weather road access, and tens of millions of people have no access to affordable and convenient transport service (ADB, 2013). It is therefore more efficient and cost-effective for those countries to implement climate assessments at the planning stages rather than fixing the system once it is complete and affected by adverse impacts (Regmi and Hanaoka, 2011). At the same time, development that increases the vulnerability of cities by ignoring climate change risks such as allowing new residential and transport developments on flood plains or reducing provisions for non-motorized transport should be avoided. Costs of adaptation hence are intimately dependent on mitigation efforts. The more climate change impacts can be mitigated, the lower the costs for adaptation. Therefore, climate proofing of transportation infrastructure should contain both mitigation and adaptation measures so that the costs of climate adaptive transport are kept as low as possible.

4. DISASTER RESILIENT TRANSPORT

4.1 Overview

Asia and the Pacific is the world's most disaster-prone region and hence has been facing increasing natural and climate related hazard risks (UNESCAP 2014a) over the past several decades.

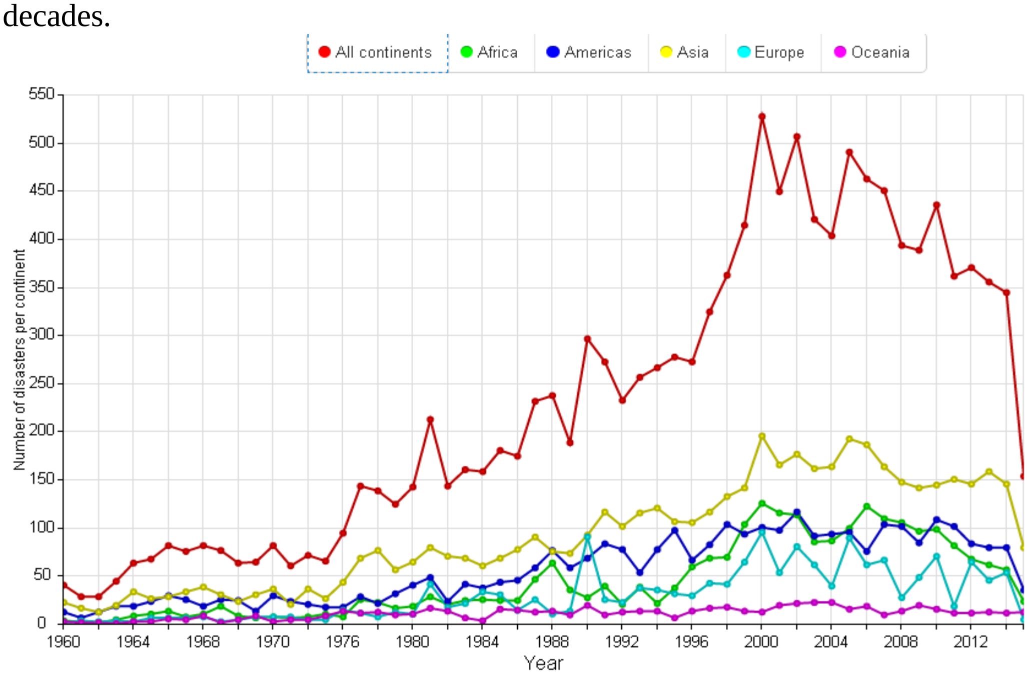

Figure 5: Total Number of Reported Natural Disaster 1960-2015
Source: CRED EM-DAT International Disaster Database, accessed 10 September 2015

Figure 5 shows the number of reported natural disasters during 1960-2015, the figure clearly shows that Asia has the largest numbers of natural disasters compared to other regions. In particular, of the world's reported natural disasters between 2005 and 2014, more than 40 per cent or 2,649 out of total 6,557 incidences occurred in Asia (CRED, 2015). Between January and

August 2015, there were 79 natural disasters reported in 25 Asian countries, of which 15 in China, 11 in India and 7 in Pakistan. The total damage amounts to nearly U.S $ 9 billion, 13,990 deaths, 19,351 injuries and 9,270,225 people affected. These figures would become worse if no further actions would be taken to combat climate change and strengthen resiliency since failure to manage disaster risks does not only threaten economic growth but can also lock countries into unsustainable development patterns. Figure 6 shows damages due to natural disasters from 1975 to 2014 in Asia. The common trend is increasing over the years, which significantly impacts economic growth and social development of countries in the region.

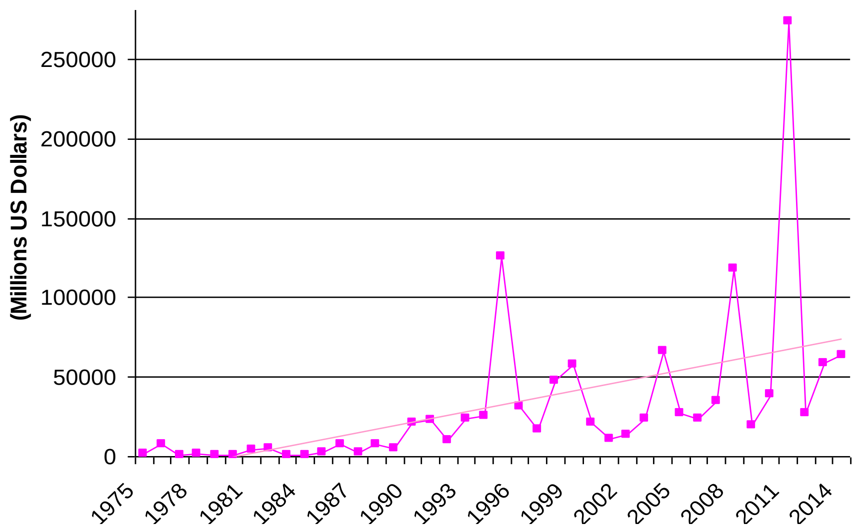

Figure 6: Losses due to all types of disasters in Asia 1975-2014 (Source: CRED, 2015)

Disaster impacts are usually calculated as total cost both to humans (number of deaths, injuries, homeless households) and to the economy (collapsed buildings, losses in productions and supply chains). Transport is often regarded as part of infrastructure. However, the detailed costs incurred to the sector and how they affect other sectors are rarely calculated in disaster assessment report for two main reasons. First, disaster-prone countries are usually low- and middle-incomes where the collection and management of data are not very consistent. Second, as transport links most economic and social activities, it is very challenging to estimate the real costs incurred to other sectors due to disrupted transportation mobility. For such reasons, the need to gather and calculate data in addition to conduct cost-benefit analysis is very necessary for policymakers and related stakeholders. Furthermore, transport infrastructure costs large investment and takes long time to implement and is usually expected to last for decades. Investment in transport hence is a big share of the government's expenditure and should be spent efficiently. That means such infrastructures should be able to survive and sustain through changes and adverse impacts. It would be very helpful for policymakers and involved partners to have such assessments in hand for project planning and implementation.

Asian cities are among the most vulnerable to natural disasters and climate change induced events. Many cities and provinces in Asia have long coastlines and informal settlements located in fragile environmental areas, making the habitats extremely vulnerable to sea level rise, floods, and cyclones. For instance, a case study for Viet Nam finds that sea level rise through 2050 could increase the effective frequency of the current 100-year storm surge of roughly five meter once in every 49 years, affecting approximately 10% of Hanoi's GDP (Neumann et al., 2015).

The Pacific Small Island Developing States in the ESCAP region are extremely vulnerable to natural disasters and climate change induced events. Given their location which is far from main international trading routes in addition to the diseconomy of scale, disaster events would significantly impact their economies. The 2014-2015 period has been one of the most active in terms of number and intensity of cyclones for the Pacific. A total of 9 cyclones were observed in Pacific Small Island Developing States with five of these having significant humanitarian consequences (OCHA, 2015). In particular, in April 2014, just a few months before the Third International Conference on Small Island Developing States was held in Samoa, the Solomon Islands was heavily hit by one of the largest flash floods in the nation's history. The flash floods killed 22, displaced 10,000 and affected 52,000 people, almost one tenth of the total population (IFRC, 2014). Major infrastructure such as roads, housing, sewerage and water supply systems were seriously damaged or destroyed. Total damages and losses were estimated at US $107.7 million, equivalent to 9.2% of the country's GDP and the two sectors that sustained most of the damage were housing at 56% and transport at 23% (IFRC, 2014).

Given large coastal area as well as the high vulnerability to natural disasters of Pacific Small Island Developing States, improving access to markets and social services and building integrated transport systems that are resilient under adverse impacts are essential. Without proper infrastructure and policy intervention, vulnerable and isolated communities will lack access to public services, markets, economic and social development opportunities. The Samoa Pathway paves the way for sustainable development in the Pacific Islands, and includes concerns of transport need of the Pacific Island countries and focus on sustainable framework and emphasizing the role of resilient transport. At the conference, member countries agreed to continue and enhance support to gain access to environmentally, sound, safe, affordable and well-maintained transportation and to develop viable national, regional and international transportation arrangements. Resilient transport can help mitigate destructive consequences resulting from natural disasters and also promote trade and economic prosperity for small island developing countries. The Sendai Framework on Disaster Risk Reduction 2015-2030 adopted in March 2015 aims to work toward enhancing safety and resiliency against natural disasters. The framework further emphasizes the need of resilient transport for disaster risk reduction.

4.2 Roles of Transport in Disaster Risk Reduction

Based on previous sections, it can be seen that transport is an irreplaceable means of mobility for economic and social activities under business-as-usual circumstances. When natural disasters occur, the role of transport becomes even more critical. For instance, once roads are impassable, communities are likely to be isolated from goods, services, markets, schools, and hospitals, etc. With roads blocked and waterways flooded, residents are not able to evacuate from affected area to safer locations. Airport closures and canceled aviation services also delay recovery response. In addition, damaged transport infrastructure, if not fixed in time, would further exacerbate the aftermath of a disaster and prevent societies from resuming to their normal operations. The reconstruction time of transportation infrastructure tends to be longer than other infrastructure. Transport infrastructure such as terminals is capital intensive and hence requires more specialized equipment for reconstruction; blocked highway and rail routes need time to be cleared and to restart normal service.

Transport connectivity also plays an important role as most routes are connected. When one route is blocked or damaged, traffic in other routes are likely to be impacted as well. Indeed, the interconnectivity of transport infrastructure can lead to a domino effect causing disruptions that might be even larger than the disaster itself (Eichhorst 2009). As a result, when a natural disaster happens, disrupted transport network limits governments and international agencies' relief efforts as many organizations depend on road and aviation transport to deliver aids. Such hindrance would expose already vulnerable communities to higher risks.

Moreover, transport infrastructure shares a large proportion in government expenditure, especially in developing countries. When natural hazards happen and damage infrastructures, the governments have to use their limited budget to fix or replace damages while such expenditures could otherwise have been utilized for improving and expanding other infrastructure, making them more resilient for future disasters. In other words, resources should be allocated to make critical infrastructure lasts through major adverse weather events rather than to fix and replace damaged networks. While economic development usually receives priority, appropriate amount of investment should be devoted to building resilient system including resilient transport. Although climate proofing and disaster resilient transport infrastructure projects can add in extra costs, these measures can help reduce cost of future maintenance and ensure that infrastructures remain operational in the long run. Co-benefits can also be larger as resilient transport can reduce costs incurred in other sectors such as production and consumption, healthcare and education. Therefore, cooperation between resilient transportation and other sectors would result in efficient financing as well as generate many co-benefits.

4.3 Lessons learned from the 2011 East Japan Earthquake

The 9.0 magnitude East Japan Earthquake in March 2011 is one of the most catastrophic natural hazards in modern human history. The earthquake and its subsequent tsunami took away 19,846 lives and affected 368,820 people (CRED, 2015), costing the country approximately U.S. $235 billion (World Bank, 2011). Japanese transport system suffered severe damages with road closures, flight delays and rail cancellations. In particular, right after the earthquake, 15 expressway routes and 69 sections on the national highways were closed (Kawasaki, 2011). All ports were closed for a short time, and the 15 ports impacted by the disaster were not fully reopened until the end of March (Nihon, 2011). 62 out of the 70 railway lines run by East Japan Railway were affected to various degrees, 23 railway stations and 7 lines were completely destroyed (Nihon, 2011). The Sendai airport incurred massive losses because the flood following the tsunami while both Tokyo's Narita and Haneda airports were closed for about 24 hours (The Aviation Herald, 2011). In addition, thanks to the alarm system that reached transport management teams in time, many major rail trips were canceled just before the hazard, avoiding disastrous accidents and reduced life losses (Koresawa A and Yawawaki Y, 2011).

Figure 7: Damage to road embankments by the East Japan Earthquake (Sources: Motoda, 2013)

As part of Japan's relief and recovery efforts, securing emergency traffic networks and bringing back normal transport infrastructures were given priorities. The utmost priority for transport is clearing roads to secure traffic of emergency vehicles, followed by emergency recovery to enable traffic of general vehicles and rehabilitation to repair roads while allowing general traffic pass-through (Kawasaki, 2011). Thanks to lessons learned from past earthquakes, Japan had revised infrastructure standards as well as associated seismic reinforcements. This helped significantly reduce damages on bridges. In particular, among the 1,528 highway bridges, five of them were washed away by the tsunami, but none were collapsed by the earthquake (Kawasaki, 2011). In regard to evacuation and recovery response, alternative routes played an essential role. For instance, the freight transport routes along the Sea of Japan functioned as an alternative to the damaged coastal routes along the Pacific. Months following the earthquake, it was observed that traffic in this alternative route increased by 30 to 50 per cent, indicating the importance of redundancy for transportation in disaster-prone region. Last but not least, communication regarding affected transport routes with up-to-date information on availability was critical in informing traffic users to plan trips or avoid blockages. Given the fact that Japan is one of the most prepared countries in the world for earthquake disaster risks, there are still many lessons to learn from this hazard, giving other countries opportunities to strengthen their resilience capacities, especially for transport sector.

4.4 Lessons learned from the 2015 Nepal Earthquake

The 7.8 magnitude earthquake in Nepal on 25 April 2015 together with its aftershocks is an apparent example of how natural disasters can devastate and lock developing countries into unsustainable development patterns. The disaster affected almost half of Nepal's districts including isolated mountainous areas, killing almost 9,000 people and injuring 22,000 others (Government of Nepal, 2015). According to the Post Disaster Needs Assessment Report, economic losses to the country were almost U.S. $10 billion, which is nearly half of its GDP. Estimated cost for earthquake recovery is an additional U.S. $ 5 billion (Government of Nepal, 2015). Unlike the East Japan Earthquake, this natural hazard occurred in one of the world's least developing countries which are very vulnerable to disasters, having low quality resilient infrastructure and large population who are already very poor.

Transport infrastructure, an integral part of evacuation and recovery response, was heavily damaged. A small percentage of the Strategic Roads Network essential for economic development was completely damaged and washed out. Side drains, culverts, retaining walls and pavements were damaged. Some of the roads were partially or fully damaged by landslides and would become worse once the monsoon season comes. Given Nepal's landlocked geography and mountainous landscape, aviation is the best way for international aids delivery. Within few following days after the earthquake, more than 4,000 rescue workers flew in Kathmandu international airport with aid supplies (Schlumberger, 2015). However, high traffic to and from disaster areas quickly damaged the airport so that it was closed for heavy aircrafts, postponing recovery plans and limiting access to the hardest-hit villages which could not be reached by roads. As a result, Nepal faced socio-economic hardship and access to education and healthcare facilities and production centres was severely affected in earthquake hit districts. Table 2 sums up damages and losses incurred to transport sector as resulted of the April earthquake and its aftermaths.

Table 2: Summary of damages and losses

Subsector	Disaster Effects (NPR million)			Share of Disaster Effects	
	Damage	Loss	Total	Private	Public
Strategic Road Network (SRN)	4,589	526	5,115	-	5,115
Local Road Network (LRN)	12,485	4,274	16,759	-	16,759
Civil Aviation	114	130	244	-	244
Total	17,188	4,930	22,118	-	22,118

Source: Government of Nepal, 2015

One of the biggest concerns for evacuation and recovery after the earthquake was to get access to people who were cut off in remote valleys and isolated mountainous areas, those who are often the poorest and most vulnerable. Furthermore, landslides resulted from the monsoon season following the earthquake have destabilized slopes increased the risk of additional landslides. Inclement weather would also hindered aviation services. Such challenges raise the need for strengthening resilience infrastructure in Nepal, both efforts from the country as well as supports from international community will be require for capacity building, technical and financial support. Lessons learned from the East Japan Earthquake proves that resilient transport infrastructure including disaster risk measures, redundant roads, and up-to-date communication plays an essential role in relief, recovery and build back better strategies.

4.5 Incorporating Disaster Risk Management in Transport Sector

As discussed in previous sections, there should be no confusion about the key roles of transport sector in both business-as-usual and natural disaster scenarios. Once a disruptive event occurs, a resilient transport network allows promptly evacuation and emergency response, aids delivery and also helps bring communities back to normal functioning. Therefore, incorporating disaster risk and climate measures in transport planning and implementation can generate economic, social and environmental co-benefits. In particular, a World Bank paper assesses this resilient approach to transport, combining the overlapped work of transport, disaster risk reduction, and environment protection to create a more efficient, sustainable and resilient outcome (World Bank, 2013). It requires the corporation of different sectors as well as the availability of risk measure data.

In addition, building a transport system that is resilient to natural disasters requires policymakers to take into account the whole life cycle approach of investing and managing infrastructure as well as constantly update risk assessments during its life cycle. It is also necessary to implement climate and disasters proofing measures and follow up with maintenance efforts.

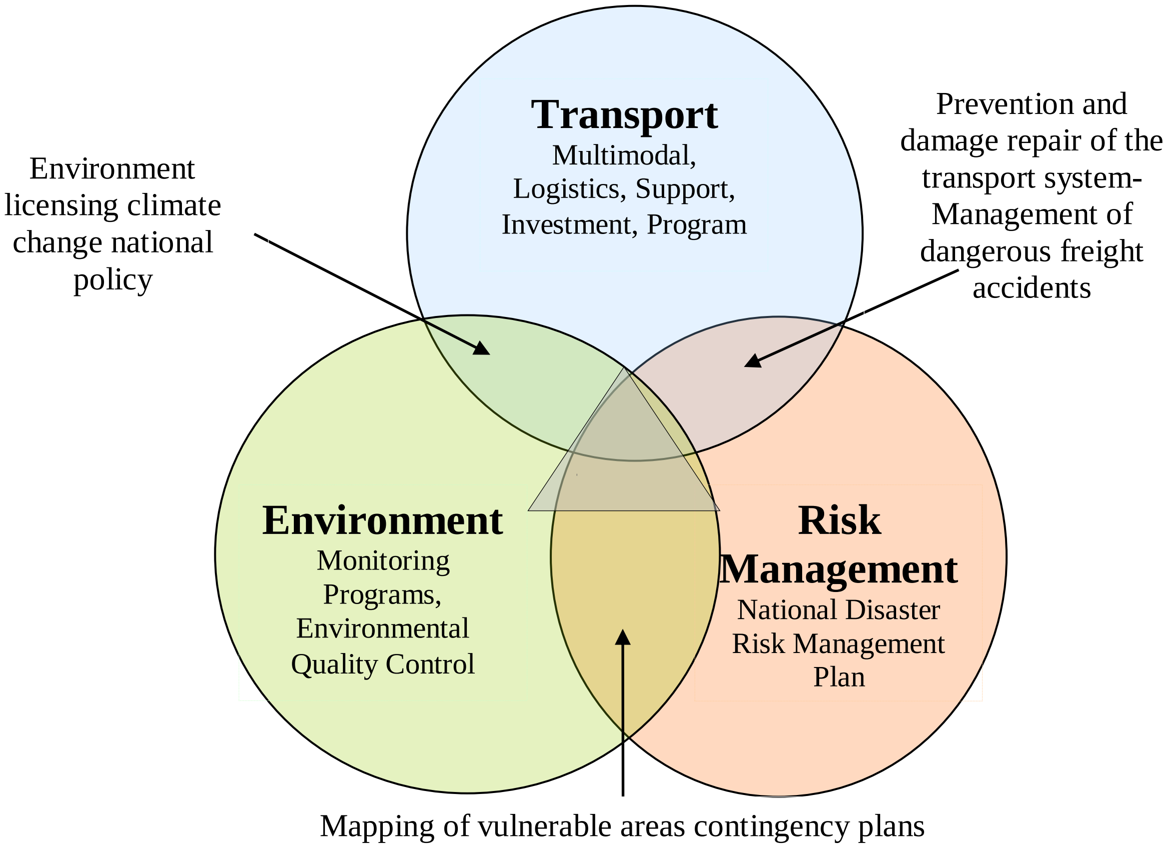

Figure 8: Resilient Transport Framework (Source: Adapted from the World Bank, 2013)

5. THE WAYS FORWARD

A safer, more climate adaptive and disaster resilient transport system would provide better quality of life as well as enhance economic efficiency. The dilemma of economic development and transport sustainability and resiliency is not a question to ponder. There is a wealth of knowledge and best practices already available in the region, from which other countries can draw upon and replicate and choose a possible pathway for developing safe, climate adaptive and resilient transport that supports economic growth.

Based on forgoing discussion of the issues and challenges faced by the transport sector in the region following policy suggestion are offered for consideration that could help to develop safe, climate adaptive and disaster resilient transport system with a vision toward building sustainable and resilient societies in the Asia-Pacific region.

5.1 Integrated transport planning

Countries, cities and local authorities should consider developing integrated transport master plan that captures short term, medium term and long term vision of transport development. There are practices in some countries to develop district, city and village profiles and develop development plans based on the data and need-rather than taking a project based approach. Authorities should ensure implementation of plan as well as periodic updating. The integrated transport plans should ensure physical integration between modes, operational integration to facilitate the functioning of physically linked modes; and service integration, such as common/combined fare ticketing system and have compatible schedule.

5.2 Prioritize public and non-motorized transport

The growing number of private vehicle ownership that has led to increase in traffic congestion and accidents. Further lack of quality NMT infrastructure has led to high accident rate involving the VRU. Authorities need to improve quality of public transportation systems, footpaths and cycle tracks to facilitate mobility. BRT is becoming a popular mass transit option in Asia and many cities are improving NMT infrastructure. For example, Chennai city in India has set a goal to build safer and continuous footpaths on at least 80 per cent of all streets, increase the share of walking and cycling trips to over 40 per cent, and eliminate pedestrian and cyclist fatalities by 2018 (Aswathy, 2014).

5.3 Improve safety of transportation systems

Safety is becoming an alarming issue and this need to be tackled by a coordinated approach-as many stakeholders and government agencies are involved. Firstly, country should develop national transport safety policy and designate lead authority for road safety. Then targeted safety interventions should be planned based on data and analysis. In order for policymakers to plan and implement safe and resilient projects, more work is needed to help understand the full economic costs of transport accidents and as well as to assess the performance of current policies that aim to reduce such risks. Focused programme relating to road safety, railway safety, and maritime safety are necessary.

5.4 Identify critical transport infrastructure

Recent climate and disaster events have caused tremendous damage to transport infrastructure and operations. As it will be costly to climate proof all transport infrastructure, it is advisable to identify critical transport infrastructure (roads, railways, bridges, maritime ports, inland and river ports, airports) that would continue to be operational and least affected when exposed to potential climate events and disasters (UNESCAP 2013a). Such adjustment would incur higher costs but assessment of life cycle costing should be carried out to make sure the long-run utilization compensates the initial incremental costs. This would also require enhancing capacity of planners and designers to foresee and visualize the likely impacts and incorporate appropriate measures such as higher design standards.

Once a disaster occurs, it is important to have alternative transport modes and routes for evacuation and recovery response. Traffic is usually distributed among different options including road, rail, water gateway and aviation. Planning should reflect the functional hierarchy of transport networks, such as primary trunk roads, national highways, feeder and district roads, and rural roads so that reconstruction after disasters would be prioritized in the most critical infrastructure (UNESCAP 2013a). For example, during the East Japan Earthquake in 2011, the embankment section of the expressway along the coast protected the inland side from inundation, saving lives and economic loses (UNESCAP 2013a).

5.5 Transport demand management

Countries should consider polices that are needed to discourage the use of private vehicles such as eliminating subsides for private cars and taxis, restricting parking spaces, congestion charging, and implementing high-occupancy lanes. In Singapore, for example, the introduction of electronic road pricing reduced total traffic within the cordon area by 14% and increased travel speed by 22% (Strompen et al., 2012). Another rising trend is the promoting of "compact cities", or cities which are designed with living, working, recreational and shopping facilities to each other, thereby reducing the need to travel. Tianjin Eco-city in China is planned around, among other things, the concept of green transport with the aim of increasing trips using public transport, walking and cycling Eco-park in Hanoi, Viet Nam is a successful model of compact cities, providing a mix of land uses and physical infrastructure for the promotion of public transport, walking and cycling. In addition, in order to reduce the dependency on private transport modes, policies to promote public transportation and enhance its affordability, reliability and accessibility are very essential.

5.6 Explore use of electric vehicles and alternate energy

Even though the vehicle technology and commercial availability of electric vehicles in market especially concerning range, performance, charging infrastructure and charging time is still evolving. Countries should explore use of alternate energy in transport to ensure energy security. Countries having high potential to develop hydropower need to initiate policies to promote use of electric vehicles. Countries could also consider exploring use of CNG and LPG, where applicable/feasible by retrofitting the fossil fuel vehicles.

*5.7 **Use of ICT and Intelligent Transport Systems***

Countries and cities could consider using appropriate ICT and ITS to improve the efficiency and safety of transport systems and to avoid need to travel by teleworking, webinars, electronic bill payment etc and to provide emergency response information to drivers.

5.8 Capacity development for data collection, analysis and design

Evidence based policy making and planning responses needs quality data and analysis. Many developing countries lack capacity to collect quality data and analysis related to traffic accidents, climate and natural disaster risks, therefore there is a need to enhance capacity of officials and to establish/improve database. Further, engineers, designers and consultants involved in planning and designing of transport infrastructure should be trained to assess likely climate change impacts and evaluate various design options for infrastructure with consideration of their life-cycle costs. They should be encouraged to propose innovative designs for review and approval of policy makers. Country-specific adaptation studies are required to develop adaptation strategies to plan sustainable and resilient transport infrastructure.

5.9 Improve cooperation among transportation and other sectors

Coordination at the national, regional, and local levels is important for implementing resilience strategies as climate change and natural disaster risks are widespread across sectors and extendable across scales (Regmi and Hanaoka, 2011). More importantly, as transport links many sectors within the economy, cooperation between transport and other sectors would be essential for smooth implementation of resilient transport strategies.

6. CONCLUSIONS

The Asia and the Pacific region is very vulnerable to climate change events and natural disasters. The transport system is impacted by these events, consumes large amount of energy, emits emission and has alarming safety record. While the countries are still striving to develop their transportation networks they need to consider safety, potential impacts of climate change and natural disasters while planning and designing the transport infrastructure. Planners, designers and engineers should be able to comprehend the available data, technology and assess likely impacts and propose innovative designs in planning stages as retrofitting is usually a costly option. Developing appropriate policies and strategies as outline in section 6 are necessary to enhance safety and resiliency of transportation systems, their true implementation backed by adequate human and financial resources are key success factors. For this coordinated efforts from all stakeholders, especially the commitment from policymakers, implementing authorities and institutions, as well as the private sector and grassroots communities is required. In addition, as with most long-term investments, there is a trade-off between short- and long-run policy objectives for building resilient transport. Increasing frequency of natural disasters and climate events further adds uncertainty into the planning process and climate proofing transportation systems (Chinowsky et al., 2012). Last but not least, more resources should be directed to research on resilience framework, both for individual countries but also a common framework for knowledge sharing and cooperation among countries in the region and worldwide.

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