Assessment of Impacts of Climate Change on Road Transport in Asia[1]

M. B. Regmi
Transport Division, United Nations Economic and Social Commission for Asia and the Pacific, Bangkok, Thailand

S. Hanaoka
Department of International Development Engineering, Tokyo Institute of Technology, Tokyo, Japan

ABSTRACT: This paper examines impacts of climate change on road transport and presents the finding of a survey of Asian countries. The paper discusses the need to enhance awareness, introduce adaptation policies and guidelines, review existing design standards and practices and proposes to extend the existing environmental impact assessment guidelines to incorporate climate change impacts. Availability of limited literature in the Asian context on impact of indicates further research needs in the area of climate change impacts and road transport, review of design standards and life cycle costing of adaptation measures.

KEY WORDS: Asia, climate change, impacts, design guidelines, policies

1 INTRODUCTION

Transport sector contributes to 23% of global CO_2 emissions (IEA, 2008a). Road transport is the largest consumer of petroleum among transport sector and in 2006 it consumed about 79% within the Asia and the Pacific region (IEA, 2008b). Road transport is predominant mode of transport in Asia. It carries substantial share of freight and passenger volume. There are now growing concern about the impact of road transport on the global climate as it contributes about 75% of GHG emission from transport (IPCC, 2007). There are many initiatives underway to reduce emissions from transport such as modal shift from road to rail, innovation on vehicle design, use of non-fossil fuels, and use of public transport.

The geometry and condition of road surface play a significant role in fuel consumption of vehicle. Good pavement surface imparts uniform speed and improves efficiency of vehicle operations. Therefore, well planned and designed roads with good pavement surface improve efficiency of road transport operations and emit fewer emissions.

These days the climate change is in high on global and national agenda even after the uninspiring Copenhagen Conference[2]. Countries are voluntarily taking measures to reduce emissions so as to hold the increase in global temperature below 2^0C. Road transport not only contributes to the global warming but it is also affected by the climate events.

Increase in temperature, precipitation, sea level and storm surges triggered by climate change will have significant impacts on planning, design, construction, operation and

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[1] The views expressed herein are those of the authors and do not necessarily reflect the views of the United Nations.

[2] http://unfccc.int/files/meetings/cop_15/application/pdf/cop15_cph_auv.pdf (accessed on 12 January 2010)

maintenance of road transport (Wooller, 2003). Only limited studies are available on climate change and adaptation in the transport sector in Asia and there is a need to integrate climate change considerations in national transport policies, research and development (IPCC, 2007).

In this context, this paper assesses the impacts of climate change on road transport in Asia and presents findings of a survey of Asian countries. Critical components of road infrastructure vulnerable to climate events are identified and proposals for planning and developing road considering adaptation strategies, policy and design guidelines are made.

2. CLIMATE CHANGE AND ASSESSMENT OF IMPACTS ON ROAD TRANSPORT

2.1 Climate Predictions for Asia

The IPCC Fourth Assessment Report predicts following grim pictures of climate variability in Asia (IPCC, 2007):

i. increase in temperature will vary from 2.5ºC to 4.3ºC mostly higher than global mean;
ii. summer heat spells will be longer and more intense and frequent in East Asia;
iii. precipitation will increase in most of Asia;
iv. the frequency of intense precipitation will increase in parts of South and East Asia;
v. extreme rainfall and winds due to tropical cyclones will likely increase in East, Southeast and South Asia;
vi. sea levels are likely to rise from 18 cm to 59 cm under various scenarios during the century around the .Indian Ocean and Pacific Ocean.

The above prediction is not uniform for all parts of Asia; therefore the scale and nature of impacts on road transport depends on the location and intensity of climate events. For example transport infrastructure damage done by 2007 floods was 34% of total infrastructure damage costing about US$ 363 million in Bangladesh (MFDM, 2007). The Aceh Flood caused significant damage to the transport sector amounting US$ 35 million (25% of total infrastructure cost) in Indonesia (GOI, 2007).

2.2 Impacts of Climate Change on Road Transport

Several studies have assessed and documented impacts of climate change on roads in developed countries (Wooller, 2003; Andrey et al., 2003; Harvey et al., 2004; Galbraith et al., 2005; NRCNA, 2008). Some of adaptation studies covering Asian context include “climate proofing” of infrastructure projects in the Pacific, Avatiu Harbor in the Cook Island, water resource management infrastructure in Indonesia and coastal infrastructure project in Vietnam (ADB, 2008), a road construction project in Micronesia (Hay, 2004) and road rehabilitation in Bangladesh (Tanner et al., 2007). However, most of these studies focus on short term impacts and the transport sector has received little attention (Koetse et al., 2009).

Table 1 lists climate events, its potential impacts on road and operation, vulnerable infrastructure components and related design parameters. In many instances it is not be possible to quantify the impacts and qualitative assessment are used to express impacts (ADB, 1996). For quantitative assessment of impacts site specific details study is required.

Some of the secondary impacts of climate events are that traffic disruption due to flooding and heavy snow and rains, difficult driving conditions, postponement of travel during such events, induced slow speed of vehicle may reduce severity of accidents but probability of accident is increased due to slippery pavement surface.

Table 1: Climate events, potential impacts, vulnerable infrastructure and related design parameters

Climate events	Potential impacts	Vulnerable infrastructure and design parameters
Temperature	The extended warm weather would affect pavement deterioration due to liquidation of bitumen, heating and thermal expansion of bridges and buckling of joints of steel structure. Decrease in temperature would affect road transport operation, operation and maintenance cost will increase for additional snow and ice removal as well as additional costs of salts to be used for snow melting.	Pavement: Use of stiff bitumen to withstand heat in summer, soft and workable bitumen with solvent in winter, control of soil moisture and maintenance planning Steel bridges: Selection of material, provision of expansion joints, corrosion protection
Rainfall	Increase in intensity of summer and winter precipitation would create floods, affect drainage, road pavement, driving condition and visibility, affect bridges and culverts waterways and clearance, damage bridges and culverts foundation due to scouring. Rainfall would trigger landslides and mudslides in mountainous roads and could create road blocks.	Bridges and culverts: Flood estimation, return period, design discharge, high flood level, free board (clearance above high flood level), length of waterway, design load, wind load, foundation, river and bank protection, corrosion protection Drains: Discharge estimation, size and shape of drain, drain slope Mountainous road: Slope protection work, subsurface drains, catch drains Pavement: Increase road surface camber for quick removal of surface water, frequency of maintenance, design of base and subbase and material selection
Storms and storm surges	Rainfall and winds associated with storm/cyclone would create flooding, inundation of embankments and affect road transport. Disrupt traffic safety and emergency evacuation operations, affect traffic boards and information signs.	Drains and cross drains: Capacity enhancement, slope Road embankment: Increase height Road signs: Wind load, structural design, foundation, corrosion protection
Sea level rise	Rise in sea level would affect the coastal roads, may be need to realign or abandon the roads in the affected areas.	Coastal road: Protection wall, additional warning signs, realignment of road sections to higher places, edge strengthening

2.3 Adaptation Strategy

The adaptation strategies and measures to be taken depend on the scale of impacts, location and topography. To overcome the impacts of climate change on the vulnerable road infrastructure listed in the table 1 due consideration should be given to the corresponding design parameters and adaptation measures.

Multilateral institutions have just started to integrate adaptation concern in their programmes and streamlining responses to climate change policy in development planning (Burton et al., 2004). Most of these approaches are general but not transport sector specific. Of the six case studies reviewed by the OECD not a single case was related to transport (Agrawala, 2005). There is gap in understanding climate change impacts, adaptation and its costs (Mills et al., 2002). Adaptation must be considered in an intergraded manner locally, nationally and internationally by mainstreaming adaptation concerns in development planning and policy (Srinivasan, 2006).

Costing is a key factor in deciding the adaptation measures. There are limited research in costing and life cycle costing of adaptation measures in transport sector (Agrawala et al., 2008). Highway agencies in US have mainly applied life cycle cost analysis in road pavement but not extensively for other road structure (Ozbay et al., 2004). Opportunities and risks of climate change and disasters methodology applied in pilot projects in India and Bangladesh can help development organizations and their partners to integrate risk reduction and adaptation processes into their programmes (Tanner et al., 2007). In one of the transport project in Bangladesh the study have evaluated and found that options of raising road embankment height from 0.5 to 1.0 m to protect the road from flood it was an economically viable option. Developed countries and multilateral banks need to show greater commitments to fund climate proofing of development projects (Bouwer et al., 2006).

There are growing arguments that current design standards may not be sufficient to accommodate climate change and there is a need to develop new design standards to address future climate conditions and projects in highly vulnerable locations should be built with higher standards (Wooller, 2003; NRCNA, 2008). A Scottish study recommends revising the storm design parameter used in surface drainage, bridges and culverts and to review design return period (Galbraith et al., 2005). Adopting design change is a time consuming process. Introduction of superpave binder in US took 25 years as a new standard despite scientific evidence of its benefits (Meyer, 2008). The increase in clearances of bridges after the Hurricane Katrina (Meyer, 2008) and incorporating one meter sea level rise in designing the Confederation Bridge in Canada (Andrey et al., 2003) are some examples of design review. Local authorities in US are planning to outlaw transport and infrastructure development in vulnerable coastal area (NRCNA, 2008) and studies advocate integrated transport and land use planning in vulnerable area (Dasgupta et al., 2007).

Klein et al. (1999) doubt the usefulness of IPCC guidelines (Carter et al., 1994) for assessing climate change impacts and adaptation which focuses more on implementation and suggest a four step approach collaboration, coordination, policy formulation and implementation. Climate change impact assessment would help to systematically plan and implement adaptation policies, as the impacts are widespread coordination is essential.

3. SURVEY OF CLIMATE CHANGE IMPACTS ON ROAD TRANSPORT

3.1 Methodology and Questionnaire Development

A survey was conducted to assess the level of awareness of policy makers and general public,

response to climate events related emergencies, existence of design standards and practices, and policies, institutional arrangements and coordination. A questionnaire consisting of 28 questions divided into four sections was developed incorporating comments and suggestions received during a pre-test and was sent by emails to transport professionals working within transport ministries and road agencies from 30 Asian countries were selected for the survey based on the existing contact with the authors. The Pacific Island countries were not included in the survey due to lack of contacts even though they will be affected by the climate events.

Total 24 responses from 21 countries (30% response rate representing 70% of countries) representing all four subregions within Asia were received namely from: Azerbaijan; Bhutan; Cambodia; China; India; Indonesia; Iran; Japan; Kazakhstan; Kyrgyzstan; Malaysia; Mongolia; Myanmar; Nepal; Pakistan, Republic of Korea; Singapore; Thailand; Turkey; Uzbekistan; and Viet Nam. Figure 1 shows the respondent's details. Most of the respondents were senior transport officials with more than 10 years of experience and some of the respondents mentioned that they had consulted officials working in environment and climate change while completing the questionnaire. Therefore, responses are considered accurate without much bias. However, caution should be taken in utilizing and interpreting the results.

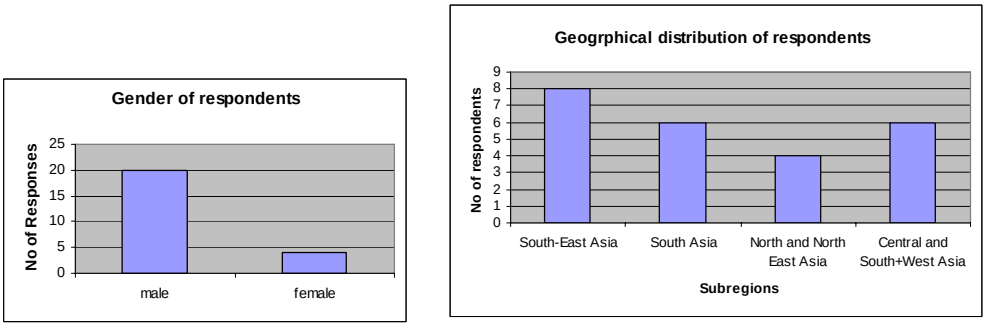

Figure 1: Gender and geographical distribution of respondents

3.2 Finding of the Survey and Adaptation Measures

3.2.1 Awareness of Climate Change and Adaptation

Figure 2 shows the different level of perception of awareness of policy makers and general public about the climate change and environment agenda among the government officials and general public. It could be as a result of ongoing climate change advocacy programme has reached to the government officials but not sufficiently reached to the general public.

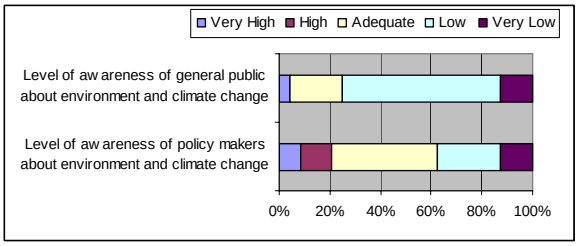

Figure 2: Awareness level of policy makers and general public

Despite numerous global efforts in tackling the issues of climate change, the level of understanding and coordination has yet to be matched with the requirement. This is similar to situation in United States and United Kingdom having still some scope to improve awareness

in the transportation sector (Wooller, 2003; NRCNA, 2008).

All but one respondent (96%) indicated the need for an awareness programme on climate change. The survey demonstrated the need of environmental and climate change awareness programme targeting all stakeholders including policy makers, project officers and managers as well as general public involved in planning, design, construction, operation and maintenance of road transport.

3.2.2 Emergency Preparedness

Road transport plays vital role in mobilizing immediate help and relief to the affected area. All respondents indicated that there had been occurrence of extreme climate events within last three years. Figure 3 shows that the level of response and relief coordination of government agencies during emergencies was adequate. All respondents except two indicated that there is some scope of improvements in the way how the help and relief operation is being managed as was indicates by the percentage of low and very low response.

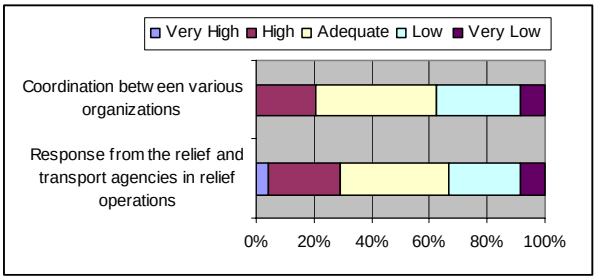

Figure 3: Level of response and coordination during emergencies

Respondents from Azerbaijan, China, Indonesia, Iran, Japan, Kyrgyzstan, Mongolia, Myanmar, Singapore, Turkey, Republic of Korea and Uzbekistan indicated that there has been some policy initiatives and improvement in dealing with emergency preparedness after recent climate events.

Further, the survey clearly showed the scope of improving coordination among various relief and transport agencies dealing with evacuation planning and emergency relief operation. Also, road transport infrastructure along important routes would require more frequent inspection and monitoring of condition.

3.2.3 Design Standards and Practices

Figure 4 shows the cumulative responses to the fourteen design standards and practice related statements which clearly demonstrate that rain and flood related damages are major cause of concerns in Asia. The low ranking of the statements related to the issues of coastal roads and snow impacts could be because the Pacific Island countries were not included in the survey and less response received from countries experiencing severe cold climate.

Figure 5 shows the response to design and policy related questions which indicates the need to consider climate change impacts in planning and designing transport infrastructure, review design standards, need of clear policy and guidelines for assessing climate impacts.

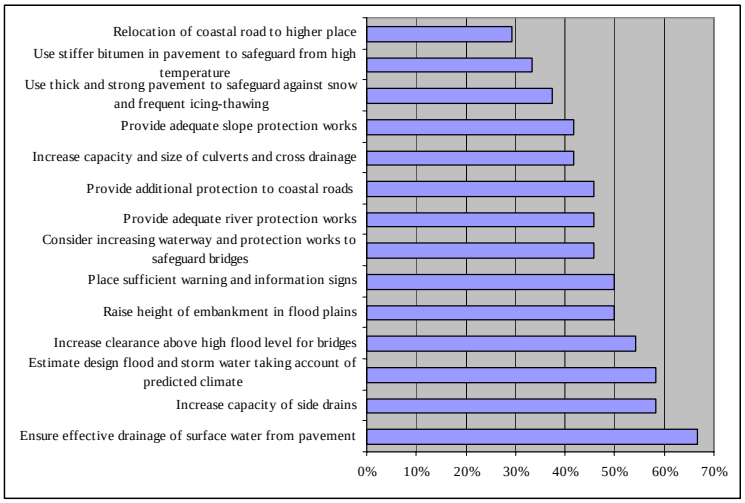

Figure 4: Response to design standards and practice related statements

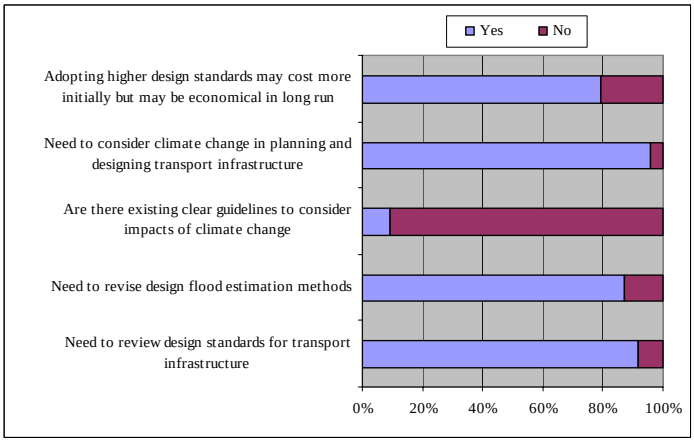

Figure 5: Response to design and policy questions

It also confirmed the need to review design standards in relation to forecasting design discharge, free board, height of embankments and additional protection measures necessary for critical components of transport infrastructure such as drainages, bridges, culverts, pavements, coastal roads, and slopes. Adopting new design standards is relatively easy at the planning stage. As indicate by the survey in many cases it may be beneficial to review the design life of various components of the transport infrastructure.

3.2.4 Policy, Institutions and Coordination

Figure 6 shows that the majority of respondents indicated that there are no existing laws, rules and guidelines to assess environmental and climate change impacts. Respondents from Bhutan, India, Indonesia, Iran, Kyrgyzstan, Mongolia, Nepal, Republic of Korea, Thailand, and Turkey indicated that there are existing laws, rules and guidelines. But most of the laws, policy and guidelines listed are related to the environmental, global warming, air pollution and very few were related to road and climate change. Most of the respondents favoured extension of existing environmental guidelines to include the climate change and adaptation.

The environmental impact assessment (EIA) process which includes assessment of potential environmental impacts, planning, implementing and monitoring mitigate measures

during construction and operation, is well recognized and followed in Asia. In the beginning the environmental guidelines (UN 2002, ADB 2003) could be appropriately extended and revised to take account of risk and uncertainty of climate change and incorporate the effect of predicted climate events into project design and to enhance understandings of climate change (Lemmen et al., 2004). It would be relatively easier to expand these guidelines rather than developing new guidelines which may take long time.

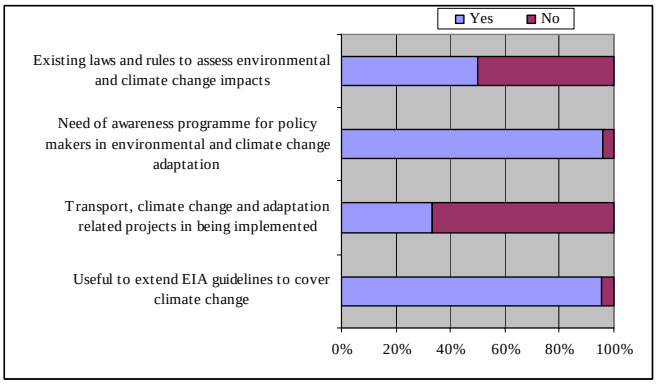

Figure 6: Response to policy and institutions related questions

Most of the respondents (83%) indicated the existence of central level coordination body responsible for environment and 61% indicated the existence of a coordinating unit/division in the line ministries and road/ highway department. Figure 7 shows the response to questions related to coordination and level of implementation of existing environmental polices, rules and guidelines which clearly indicated the need for greater collaboration and effective implementation of policies and guidelines.

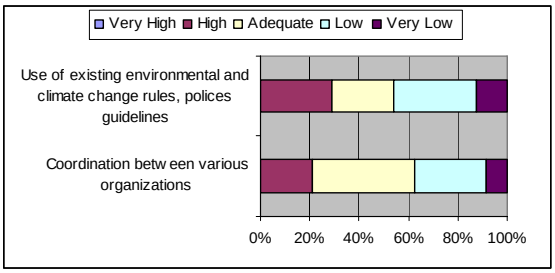

Figure 7: Response to questions on coordination and policy implementation

The survey also revealed the need to establish organizational units responsible for dealing with climate change issues within line ministries and road agencies. The capacities of these organizational units need to be strengthened through provision of trained professionals so that they could effectively coordinate, advocate, initiate and implement climate change policies. The impacts of climate change could be widespread as well as localized therefore coordination at central, regional and local level is essential while planning and implementation adaptation measures.

3.2.5 Additional Feedback from the Survey

The respondents made additional suggestions to: undertake detail study of impacts on transport; increase planning and design time horizon; ensure adequate periodic supervision of

transport infrastructure; evaluate technical and economic viability as well as life cycle costing of the proposed design; plan adaptation measures on the capability and affordability of the country; provide adequate funds for road transport development and maintenance.

Many survey respondents have sought technical as well as financial support to initiate adaptation projects in Asia. Funding support could be available from Global Environment Facility (GEF) and the United Nations Framework Convention on Climate Change. But there are very few adaptation projects on transport sector within Clean Development Mechanism under the Kyoto Protocol and the GEF (Wright et al., 2005). Asian Development Bank (ADB) has recently established climate change fund. Countries should initiate more transport projects under CDM and explore ways to mobilize technical and financial resources for planning and implementation of climate change adaptation measures.

4. CONCLUSIONS

This paper highlighted importance of planning and designing road transport infrastructure considering the likely impacts of climate change, listed vulnerable infrastructure components and key design parameters. The survey of Asian countries identified the need to advocate and create greater awareness among policy makers, managers and general public; initiate polices and extend environmental guidelines to include climate impacts; review design standards and practices; establish organization units and enhance coordination among various stakeholders. Adaptation measures in road transport are costly and it takes time to mainstream the process. The increased level of awareness and coordination among all stakeholders would be essential for development of sustainable road transport. Availability of limited literatures on transport and climate change studies in Asia indicates further research needs in area of country specific impacts assessment, quantification of impacts, costing adaptation measures and review of design and guidelines for developing resilient infrastructure.

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