Climate Change and Transport: Assessment of Freight Modal Shift and Emissions through Dry Port Development

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ABSTRACT

The recent frequent occurrence of extreme weather events in Asia provides evidence of increased intensity and frequency of climate events. On one hand, the transport sector is affected by these climate events; on the other hand, transport system contributes to the global warming through emissions of greenhouse gases. The current research attempts to analyze and address the issues of adaptation and mitigation in the transport sector in Asian context.

Firstly, an assessment of impacts of climate change on transport was done through a survey of transport policy makers in Asia. The result showed the need to create awareness, plan and design transport infrastructure with consideration of the likely impacts of climate change and the need for greater collaboration among agencies. It also highlighted the importance of strategic environmental assessment and environmental impact assessment and identified the need to review design philosophy and consider life cycle costing while developing adaptation strategy.

With respect to mitigation, the research looked at the potential of freight modal shift through the development of dry ports. The review of selected case studies of dry ports development in Asia revealed their potential environmental benefits. It also highlighted the importance of coordination among various stakeholders and agencies during the development and operation, importance of railway connectivity and the need to improve efficiency of transport operation between seaport and dry port.

The four alternative locations of dry ports in Laos were analyzed using the analytic hierarchy process and the goal programming considering evaluation criteria such as transportation time, cost, intermodal transport connectivity, environmental impact and regional economic development. The analysis based on the feedback of policy makers and freight forwarders prioritized Thanalaeng which is close to the capital Vientiane.

Stated preference survey of freight forwarders in Laos and Thailand was conducted to develop a mode choice model and estimate potential mode shift to railways from road. The respondents were asked to choose a freight mode in given scenario of transportation time, cost and reliability of the truck and train transportation between Laem Chabang seaport in Thailand and Thanalaeng in Laos. The result showed that a modal shift of 43% from road to railways is possible in base case scenario, provided that dry port is developed and freight train service is available.

Assessment of CO_2 emission from the freight transport operation was done considering the mode shift. The result indicates a 30% reduction of CO_2 emission was possible at the base case scenario compared to business-as-usual corresponding to a 43% mode shift to railways. Scenario analysis showed that the mode shift would vary from 32% to 54% and the corresponding CO_2 emissions reduction would also vary from 23% to 39% depending on the scenario considered. Life cycle emission assessment of the construction of dry port at Thanalaeng showed that the construction emissions would be compensated by emissions reduction from mode shift within three years of start of operation of freight train service.

The application of integrated methodology enabled to explore environmental benefits of the dry ports development in addition to its function as logistics and distribution centre. The various results and information that would be useful to decision makers can be derived through application of the methodology and to make informed decision.

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CHAPTER 1

INTRODUCTION

1.1 Background

Sustainable transport development involves the provision of safe, reliable and environmental friendly transport without aggravating adverse global phenomenon. Sustainable mobility is defined as the ability to meet the needs of society to move freely, gain access, communicate, trade, and establish relationships without sacrificing other essential human or ecological values, today or in the future (WBCSD 2004). While social sustainability, environmental sustainability, and economic sustainability, the three pillars of sustainability, are equally important, the current research focuses on environmental sustainability of transport system.

Recent frequent occurrences of extreme weather events provide enough evidence of increase in intensity and frequency of climate events in Asia. The rise in temperature, long heat spells, increase in frequency and intensity of precipitation, tropical cyclones, rise in sea levels in coastal areas substantially affect transport infrastructure and system (Christensen et al. 2007). Various studies have assessed the impacts of climate events on transport in developed countries (Wooller 2003, Harvey et al. 2004, Galbraith et al. 2005). These studies showed that the climate events have substantial effect on planning, design, construction, operation and maintenance of the transport system (Andrey and Mills 2003, NRCNA 2008). However, limited studies are available in the area of climate change and adaptation in the transport sector in Asia.

Transport and climate change is a cyclic phenomenon. On one hand, transport system is affected by the extreme climate events; on the other hand, emissions from transport operations contribute to the global warming which in turns aggravates extreme climate events. It is therefore important to consider both adaptation and mitigation while dealing with sustainable transport development.

Energy consumption in the transport sector in Asia is growing faster than that of other sectors and other regions, driven by a rapid increase in motorization and strong transport demand for economic development. Within the transport sector of the Asia-Pacific region, road transport, being predominant mode of transport in Asia, consumes about 80 per cent of petroleum products whereas the share of rail is just 2%. The global energy use in the transport sector is expected to increase by 50 percent by 2030 (IEA 2009a).

Meanwhile, the transport sector is the primary source of air pollution and one of the largest contributors to overall green house gas (GHG) and CO_2 emissions. Transport sector contributes 23% of global CO_2 emissions (IEA 2009b) and road transport contributes about 75% of GHG emission from transport (IPCC 2007). Freight emissions account for about one-third of the total transport emissions.

These days the climate change is high on global and national agenda and there are now growing concern to initiate measures to reduce energy consumption and emission from the transport sector. Countries are voluntarily discussing and taking measures to reduce emissions so as to keep the increase in global temperature below 2^0C (UNFCCC 2009). To achieve this and cut down global carbon emissions, transport sector has to play a leading role.

Many researches, initiatives and policy measures on sustainable transport development and climate change focus on passenger and urban transport (Kamakate and Schipper 2009, Han and Hayashi 2008, Burwell 2009, Collantes and Gallagher 2009). These include emission reduction potential through modal shift from private mode to public transport and mass transit system, demand management through congestion charging, improvement of vehicle efficiency, and use of non-fossil fuels. Guidelines relating to passenger, urban and road transport are readily available. However, limited studies are available in the area of freight transport emission though this contributes one-third of total transport emission. As many studies cover passenger and urban transport and there is research gap in the area of freight transport.

One of the ways to address emission reduction could be through development of intermodal transport and encouraging modal shift. In order to promote intermodal transport development of transport links and nodes that include ports, airports, river ports and inland dry ports as well as improvement of efficiency of transport services is essential. Development of dry ports offers opportunity for modal shift by integrating various modes of transport.

Intraregional exports and imports are increasing throughout Asia. Exports and imports grew by over 15% year-over-year from 2007 to 2008 (ESCAP 2009b). Asia's share of world containerized exports and imports are expected to rise to 68% and 56%, respectively, by 2015. The total number of containers handled in Asian ports is estimated to reach 492 million twenty-foot equivalent units (TEU) by 2015, and the transshipment volume comprises 109 million TEU of this total (ESACP 2007a).

Development of sustainable transport systems to meet the needs of intra- and interregional trade are an increasingly important issue given the need to optimize the use of scarce energy resources and to reduce emissions. While all aspects of sustainable mobility are important, the research focuses on climate change impacts on transport, development of dry ports as an important node of intermodal transport, freight modal shift and emissions assessment.

1.2 Problem statement

Sustainable transport development involves dealing with both adaptation and mitigation. While it is essential to safeguard and develop durable transport infrastructure and system from impacts of extreme climate events, it is also important to reduce energy consumption and emissions from transport. The current research is an attempt to look at both aspect of sustainable transport.

Firstly, one way to develop sustainable transport infrastructure is to assess likely impacts of climate change and incorporate those in the planning, design and development of transport infrastructure and system. Analysis of perception of policy makers and general public towards climate change impacts on transport can provide useful guidance to plan and implement adaptation measures.

Secondly, with respect to mitigation one of the ways to reduce energy consumption and emissions from the transport sector is to promote freight modal shift. Currently freight transport is predominantly carried by road transport in Asia. In order to reduce emissions, mode shift of freight from road transport to more environmental friendly and energy-efficient modes such as railways, inland waterways and shipping is necessary.

In this respect, in order to promote modal shift, the existing transport system needs to offer choice of modes such as road, railway and inland waterways. Then there needs to have facilities such as dry port that integrates various modes and offers opportunities to change mode. There has been substantial progress in developing road and rail network in Asia. However, the development of intermodal facility is at initial stage. The strategic location of such facility can offer and motivate mode choice. Further, as emission is a function of distance travelled and tonnage carried; therefore, the location of dry port is an important consideration for promoting intermodal transport. Strategic location of dry port can reduce total ton-km of freight transported in whole logistics chain. Therefore, policies and interventions that are conducive to encourage freight modal shift are necessary. The policy should enhance the attractiveness of modal shift through provision and availability of efficient and effective modal shift services and facilities such as dry ports with further connection to sea ports.

It is also necessary to visualize how much would be the shift in mode after developing such dry port. Therefore, an estimation of mode shift and resulting emissions reduction would also be useful to the decision makers to consider policy intervention for developing dry ports and intermodal transport. This measure can supplement other efforts to reduce emissions such as vehicle technology, innovative fuels, demand management etc.

Often, multiple interventions are required to move toward sustainable transport development. The decision problem involves analysis of location of dry ports considering various factors and views of different stakeholders and estimation of modal shift and resulting emissions. The stakeholders include government decision makers as well as private sector freight forwarders and transport service providers.

Analytic Hierarchy Process (AHP) one of the Multi-criteria Decision Analysis (MCDA) methodologies (Saaty 1997) can incorporate feedback of various stakeholders and can be utilized in prioritizing and ranking alternatives. The subjective as well as objective criteria and sub-criteria that are relevant to a location problem can be incorporated in AHP (Saaty 1995). MCDA was used to evaluate alternative options for environmentally sustainable transport system in Delhi (Yedla and Shrestha 2003) and assessment of transport projects (Tsamboulas et al. 1999). A transport route that offers two mode choices linking the priority location of a dry port with sea port can be analyzed through stated preference survey to estimate potential mode share. The top-down, bottom-up approaches and life cycle assessment can be used to estimate emissions. Further, development of dry ports in secure inland location would safeguard these facilities from risk of damage from raising sea levels and storms.

In addition to its contribution toward the modal shift and emission reduction, strategic location of dry ports can play an important role in the development of an intermodal transport system and had the potential to become centers for economic development allowing more trades, particularly in landlocked countries and wider domestic hinterlands.

1.3 Research questions

In this respect the research questions that need to be further explored are:

(a) How to safeguard transport infrastructure from impacts of extreme weather events and make it more secure and safe?
(b) How to evaluate environmental benefits of dry port development and prioritize location?
(c) How to encourage freight modal shift from road to railway in order to reduce CO_2 emissions from transport?

The research thesis is that the adaptation strategies developed considering impacts of climate change can assist policy makers in developing robust transport infrastructure and facilities that provide intermodal transfer opportunities such as dry ports which can encourage intermodal transport, modal shift and potentially reduce CO_2 emissions. While further exploring the second research question, as the emissions largely depend on the vehicle-kilometre travelled, therefore the location of dry port is an important aspect to be considered.

1.4 Research objectives

In this background, the primary objective of the research is to assess the impacts of climate change on transport and mitigation potential of the dry port development. It aims to propose adaptation strategies and measures to safeguard vulnerable transport infrastructure. It also aims to review the development of dry ports in Asia, develop mode choice model and evaluate CO_2 emission from freight transport using bottom-up approach. The outcome and results of the analysis and assessment are indented to assist decision makers to make rational decisions to develop sustainable transport development including promotion of modal shift and intermodal transport.

The specific objectives of the research are:

(i). To evaluate policy maker's perception on the impacts of climate change on transport and propose adaptation strategies to safeguard vulnerable transport infrastructure;
(ii). To review the development of dry ports with an environmental perspective and analyze location of dry ports; and
(iii). To assess potential freight modal shift due to the development of dry ports and assess CO_2 emissions for various scenarios.

1.5 Research framework

The study integrates adaptation and mitigation aspects of sustainable transport development. An integrated methodology is proposed that combines adaptation policies and strategies to develop and safeguard transport infrastructure, evaluation of intermodal transfer location such as dry port utilizing multi-criteria decision analysis and multi-objective decision making, estimation of freight modal shift through use of stated preference survey and assessment of CO_2 emission.

The research takes case study and quantitative analysis approach including formulation and evaluation of quantitative mathematical models such as analytic hierarchy process (AHP), AHP-goal programming (GP), mode choice model, and emission assessment through bottom-up and life cycle analysis.

The research framework includes following four stages.

(i) **Identification of current issues and problems:** Initially, the concept of sustainability and sustainable transport, recent climate events and its impacts on transport infrastructure, trend of freight transport, energy use in transport sector, emissions from the transport sector with particular reference to Asia are reviewed to define problem statement and research objectives more clearly.

(ii) **Review of literatures and methodologies:** Works carried out in the area of adaptation and mitigation are reviewed. Based on the review, various multi-criteria decision analysis (MCDM), multiobjective decision making (MODM), and emission measurement approaches, appropriate methodology is selected for development of mathematical models.

(iii) **Data collection:** It involves development of questionnaires and data collection from government policy makers, freight forwarders and transport operators for the study. The primary data collection involves four stages: (i) perception of government policy makers on climate change impact on transport and adaptation policy and strategies; (ii) collection of case studies on development of dry ports in Asia; (iii) judgment of government decision makers, freight forwarders and transport operators on pair-wise comparison of criteria and sub-criteria and alternative dry port location in Laos; and (iv) stated preference survey of freight forwarders and transport operators in Laos and Thailand on mode choice between road and railway. Additional data relating to the costs, time, distance of the O-D route, freight volume, emission factors, and government infrastructure development policies are collected from secondary sources.

(iv) **Model analysis:** It includes evaluation of models using primary data collected, location analysis, estimation of mode shift, emission assessment, life cycle emission assessment and scenario analysis and a series of conclusions are drawn. Any need for further research is also identified within the scope and limitation of the study.

1.6 Scope and limitation

1.6.1 Scope and study area

The study focuses in Asia to assess the impacts of climate change on transport and adaption measures. Laos, one of the land locked country in Asia is selected for dry port location problem and analysis, because there is a potential to develop intermodal transport, railways and encourage mode shift. The study focuses on freight transport as there is substantial volume of trade between Laos and Thailand. Stated preference survey to estimate the potential mode shift choice and assessment of CO_2 emissions is undertaken along a transport corridor between Laem Chabang Port in Thailand and a dry port in Laos. The origin/destination point in Laos is selected after the location analysis of four alternate dry ports. Figure 1.1 shows the study area in Laos and Thailand.

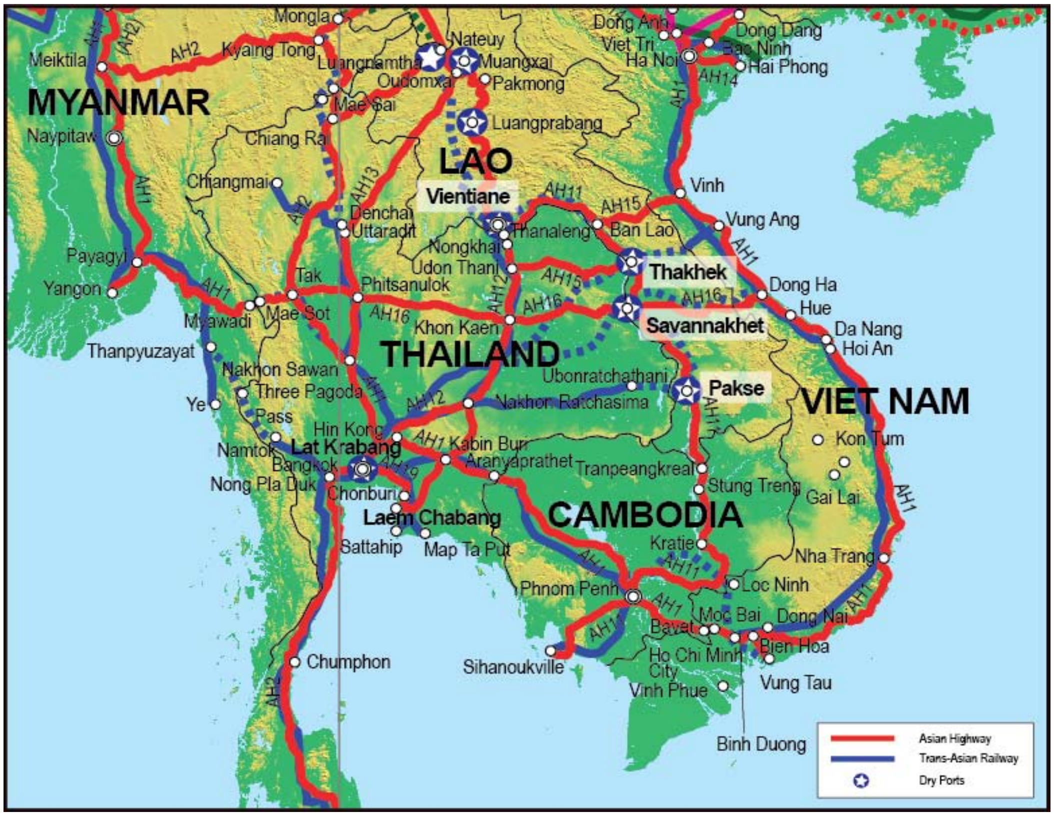


Figure 1.1: Study area in Laos and Thailand

The study is limited to the analysis of dry ports in Laos and freight transport to/from Thailand. It considers transport from seaport to dry port and does not consider domestic leg of transport in Laos. Also, the study area and four alternative dry ports are selected based on proximity to Thailand and their potential to serve international and transit transport through Laos.

1.6.2 Limitation

Survey input from transport officials and experts from Asia, government policy makers in Laos, and freight forwarders and transport operators in Laos and Thailand are used for analysis. Mode choice options only consider two choices – road and rail. Emission factors from Thailand are used in the analysis as majority of freight routes pass through Thailand. Five criteria, 12 sub-criteria and four-alternative locations are selected for AHP model to ensure more reply from survey respondents. Even this ended with 101 questions for pair-wise comparison. The results presented are reasonable and can be generalized in context with some caution in view of the limitation. Flooding in Thailand during October-December 2011 affected the collection of data from freight forwarders for the stated preference survey.

1.7 Scholarly contribution of the research

Followings are the scholarly contribution of the research:

(i) Developed integrated methodology linking AHP, AHP-GP, mode choice, bottom-up analysis and life cycle assessment to analyze dry port location problem, estimate mode shift and assess resulting CO_2 emission;

(ii) Collected four set of primary data for the research from policy makers and private sector freight forwarders;

(iii) Analyzed perception of policy makers on the impacts of climate change on transport and proposed adaptation strategies in the Asian context;

(iv) Revealed environmental benefits of intermodal transport and development of dry ports;

(v) Analyzed actual dry port locations in Laos from the perspective of government decision makers and users such as freight forwarders, transport operators, transport service providers and representatives of commerce and industries; and

(vi) Developed mode choice model and estimated mode share of freight transport through the development of dry ports, and rail service and assessed resulting CO_2 emissions as well as life cycle emissions of dry port construction.

1.8 Structure of the thesis

The thesis is presented in the following structure.

Chapter 1 presents background, research questions, objectives, and research framework.

Chapter 2 includes extensive literature review covering all aspects of sustainable transport, adaption, mitigation, ongoing research on mitigation. It further elaborates CO_2 emission assessment, development of intermodal transport and outlines MCDA focusing on AHP, goal programming, and mode choice.

Chapter 3 presents integrated methodology proposed for the study that includes assessment of climate change impacts and policies for adaptation measures and strategies, AHP and goal programming for analysis of dry port location problem, mode choice model, emissions assessment through bottom up approach and life cycle assessment and scenario analysis.

Chapter 4 presents details of survey of policy makers on climate change policies and adaptation. It presents assessment of impacts of climate change on transport analyzing the survey data received from policy makers, and proposes adaptation strategies and measures to safeguard vulnerable transport infrastructure. It also discusses how the adaptation measures in the transportation sector could be financed within framework of clean development mechanism (CDM) or other mechanisms.

Chapter 5 presents the collection and analysis of case studies of the development of dry ports in Asia. The case studies are analyzed with respect to their ownership and operational model, potential environmental benefits, potential area of improvement to enhance efficiency, and lessons are drawn.

Chapter 6 presents details on primary data collection for the location analysis that involved seeking feedback from decision makers and freight forwarders in Laos. It includes the analysis of data utilizing analytic hierarchy process and goal programming. It involves pair wise comparison of criteria, sub-criteria and alternative location of dry ports in Laos and analysis to prioritize the locations, results and discussion.

Chapter 7 presents details of data collection for estimation of mode shift through stated preference survey of freight forwarders and multimodal transport operators in Laos and Thailand. The data are analyzed to develop a freight mode choice model to choose between road and rail. The model is used to estimate potential mode shift and then emission assessment through bottom-up approach and life cycle emission assessment. It also includes discussion on the research results, measures to reduce emissions, and effects on mode shift due to variation in time and cost of each mode.

Chapter 8 presents summary of findings, conclusions of the research and its contribution and suggestions for further research.

Appendices contain supplementary information related to the research including questionnaires used for data collection.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter outlines review of relevant literature related to the current research.

Firstly, various definitions and approaches to the sustainable transport development are explained. The needs to incorporate both climate change adaptation of transport infrastructure and mitigation approach are elaborated. This then outlines adaptation and mitigation measures and measurement of emissions from transport sector. Various approaches and methods to assess transport emissions including top-down and bottom up approaches are stated. Emission factors relevant to the study area; namely, Laos and Thailand, and emissions measurement studies in transport and Asian context are elaborated. The concept of life cycle assessment is introduced highlighting various approaches of measuring emissions from the construction of dry port infrastructure.

Secondly, state of freight mode share in Asian context and the need to encourage modal shift through intermodal transport are elaborated. This further looks at the freight transport, issues of modal shift, dry port development and potential environmental benefits of such system, and illustrates dry port location problem.

Thirdly, various approaches to location analysis of intermodal transfer points such as dry ports are outlined, which include multi-criteria decision analysis (MCDA), analytic hierarchy process (AHP), goal programming (GP) and combined AHP and GP. An account of earlier research and studies in this area is provided.

Fourthly, mode choice model, design of choice experiment, choice sets and stated preferences experiment are highlighted thereby citing many similar studies used in freight transport.

Fifthly, the status of freight transport in Laos is elaborated highlighting existing freight transport system and the plans to develop dry ports, logistics centres and intermodal transport.

Finally, a chapter summary with suggestion for appropriate methodology to be used for the current research is outlined.

2.2 Sustainable transport development

Sustainable development is the development that meets the needs of the present without compromising the ability of future generations to meet their own needs (WCED 1987). Sustainable transport development involves the provision of safe, reliable and environmental friendly transport without aggravating adverse global phenomena.

There are various extended definitions of sustainable transport development. The World Business Council for Sustainable Development defines sustainable mobility as the ability to meet the needs of society to move freely, gain access, communicate, trade, and establish relationships without sacrificing other essential human or ecological values, today or in the future (WBCSD 2004). A sustainable transport system should consider three pillars of sustainability namely: social sustainability; environmental sustainability;' and economic sustainability. The first one deals with social development which elaborates the objectives of provision of safe and economical access, acceptable level of air and noise pollution and supporting achievement of the Millennium Development of Goals (MDG). The second deals with environmental protection, safeguarding the ecosystem, climate change and optimization of resources. The third deals with economic development which considers the efficiency, effectiveness and financial sustainability of the transport system.

Sustainability of transport systems is an increasingly important issue given the need to optimally use scarce energy resources and reduce emissions. In order to move towards a sustainable transport system in the region, it is essential to establish institutions that promote good governance and integrated planning, to enhance capacities of people and institutions and to use appropriate technologies that are compatible with the level of development.

Sustainability of the transport system could be greatly enhanced through innovation in design, construction and technology as well as policies to ensure funds for their development and maintenance. For example, innovation in maintenance and vehicle technology can ensure smooth operation of transport system, reduce operating costs and emissions. Whereas, innovative approaches to funding can ensure adequate funding for maintenance which in turns reduce life cycle costs and prolongs life of transport infrastructure. This research does not deal with technology innovations it however discusses the approaches to safeguard transport infrastructure from impacts of climate change, development of dry ports and intermodal transport, measures to promote mode shift, reducing emissions and policies that are relevant to freight transport.

One of the ways to address the issues of sustainability in the transport sector is to reduce energy consumption and vehicle emissions. Adaptation or mitigation alone cannot cope with all projected impacts of climate change. However, they can complement each other and can significantly reduce the risks of climate change (Pachauri 2008, Sperling et al. 2009). Both adaptation and mitigation aspects of sustainable transport development should encompass the concept of sustainability. Therefore, the attempt should be not only to look at impacts of climate change on transport but also towards reducing contribution of transport to climate change. The current research aims to look at both aspects that include adaption as well as reduction of emissions in the transport sectors considering policies and initiatives to promote modal shift to environmentally friendly transport modes such as railways.

2.2.1 Adaptation

Climate is defined as the average weather. Climate change refers to change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties, and that persist for an extended period, typically a decade or longer. Impacts refer to the effects of climate change on natural and human systems. Adaptation refers to initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects.

2.2.1.1 Climate change and transport

Frequent occurrence of extreme weather events provide enough evidence of increase in intensity and frequency of climate events recently in Asia. The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report predicts that Asia is expected to experience rise in temperature, longer summer heat spells, more intense and frequent precipitation, increase in extreme rainfall and tropical cyclones, rise in sea levels in coastal areas around the Indian Ocean and northern and southern Pacific Oceans (Christensen et al. 2007).

Transport system is affected by these climate events. Increase in temperature, precipitation, rise in sea levels and storm surges contribute to significant impacts on planning, design, construction and maintenance, and operation of road transport (Wooller 2003) as well as all modes of transport. Transport is not only affected by these climate events, it also contributes to the global warming through emission of green house gases (GHG) from operation of road vehicles. Road transport contributes about 75% of GHG emission from transport (IPCC 2007).

Some studies have identified research gaps in the area of impacts assessment and quantification, implications for design guidelines, appropriate adaptation strategies for transport sector (Lemmen and Warren 2004). The IPCC Synthesis Report suggests the need to integrate climate change considerations into national transport policies and on research and development (IPCC 2007).

Several studies have assessed and documented the impacts of climate change on transport on transport in developed countries such as Australia, Canada, Scotland, the United Kingdom and the United States (Wooller 2003, Andrey and Mills 2003, Harvey et al. 2004, Galbraith et al. 2005; NRCNA 2008, ICF 2008). These studies have shown that climate change have made substantial impacts on planning, design, construction, operation and maintenance of transportation system. These studies can provide guidance on the type of potential impacts. The climate change threatens to severely affect the basic elements of life for people around the world such as access to water, food, health and use of land and environment (Stern 2007). However, very limited studies have been conducted to cover Asian context (ADB 2008a; Hay et al. 2004, and Tanner et al. 2007).

Koetse and Rietveld (2009) have extensively examined the effects of climate change on transport and concluded that most studies focus on short term impacts with transport sector receiving little attention. Some of observed impacts listed are effects on coastal transport infrastructure due to sea level rise, effect on traffic safety and congestion on roads by precipitation, delay in rail transport, high winds and visibility have effect on safety and delay for air transport, low and high water levels affect water transport.

There are many recent examples of extreme climate events in Asia. These include intense rain and flooding in China in 1999; serious flooding in Japan in 2000 brought about by ten typhoons; serious and recurrent floods in Bangladesh, Nepal, and the northeastern states of India during 2002, 2003, 2004 and 2007; record rainfall of 944 mm in Mumbai in 2005; flooding in Sri Lanka in 2003; the Ache Food of 2007 in Indonesia; the 2008 flood in Vietnam; heavy rain and flooding in the Philippines in 2004; and flooding in Cambodia in 2000. China, Japan, the Philippines, and

South Asia were frequently hit by cyclones and typhoons during this time, and North-East Asia was subjected to several extreme snowfalls during the 2009 winter. These extreme events caused severe damage to transport infrastructure and operations.

The damage done to transport infrastructure by 2007 floods in Bangladesh was 34% costing about US $ 363 million (MFDM 2007). The Aceh Flood 2007 in Indonesia caused significant damage to the transportation sector amounting US $ 35 million that is 25% of infrastructure costs (GOI 2006).

Therefore, it can be seen that the scale of impacts on transport infrastructure depends on the severity of climate events and on the local topography, terrain, and natural conditions. Different adaptation measures and strategies would be necessary to deal with different types of impacts and topography.

2.2.1.2 Adaptation measures

In order to safeguard vulnerable transport infrastructure from the impacts of climate change planning and implementation of appropriate adaptation measures are necessary. Agrawala and Fankhauser (2008) have studied costs of adaptation measures and mention that only limited cases are available in the transportation sector. They concluded that there is a need to conduct a careful cost-benefit analysis of adaptation measures. The design of adaptation programme must be based on comparison of cost avoided with costs of adaptation.

For assessment and evaluation of impacts, the IPCC guidelines, Carter et al. (1994) recommend a standard seven-step approach: (i) define the problem; (ii) select an appropriate assessment method; (iii) test the methods; (iv) select and apply climate change scenarios; (v) assess biophysical and socioeconomic impacts; (vi) assess autonomous adjustments; and (vii) evaluate adaptation strategies. In contrast, Klein et al. (1999) doubted the usefulness of IPCC guidelines for assessing climate change impacts and adaptation which focuses more on implementation and suggested a simple four-step approach that includes collaboration, coordination, policy formulation, and implementation.

A study looked at impact of sea level rise in the coastal area but it mainly focuses on population and infrastructure planning (Dasgupta and Laplante 2007). Even though it did not cover transport, the study suggests that planning should consider all associated risks and recommends avoiding coastal and vulnerable areas while planning infrastructure. In terms of impacts they predict that Vietnam is expected to be badly affected in Asia. In addition to the Pacific Island countries, coastal mega-deltas in Asia such as Dhaka, Kolkata and Shanghai are at high risks of being severely impacted by the rise in sea level (IPCC 2007).

ADB (2008a) has initiated incorporating adaptation measures in project design and implementation. Some example includes “climate proofing” of the design of the Avatiu Harbor in the Cook Island, water resource management infrastructure in Indonesia, and coastal infrastructure project in Vietnam. ADB’s adaptation programme for the Pacific has initiated “climate proofing” of some infrastructure projects. One of the road construction projects being implemented was in Micronesia (Hay et al. 2004).

2.2.1.3 Design review

Many literatures have indicated that it may be beneficial to review the design life of various components of the transport infrastructure. Many studies have suggested that as current design standards may not be sufficient to accommodate climate change and stressed the need to develop new design standards to address future climate conditions. The projects in highly vulnerable locations should be built with higher standards (Wooller 2003, NRCNA 2008). Short (2009) has outlined that there is evidence already that our infrastructure design standards need to be re-examined to better deal with the consequence of climate change.

Meyer (2008) argued that US highway design standards developed 50 years ago, may not be sufficient to accommodate the impacts of climate change while examining potential changes in design and engineering practices due to climate changes in the US. He suggested that projects in highly vulnerable locations should be built with higher standards and stressed the need to review the current US highway standards and develop new design standards to address future climate conditions. He mentioned that design change is a time consuming process and gives an example of introducing "superpave" binder that took 25 years for its adoption as a new standards despite scientific evidence of benefits. Robert (2007) has looked into the issue of climate change and mobility management.

Meyer (2008) further mentioned that the clearance of bridges have been increased after the Hurricane Katrina. One meter sea level rise was incorporated into the design of Confederation Bridge in Canada (Andrey and Mills 2003). Dasgupta and Laplante (2007) suggested integrating transport and land use planning to consider vulnerable area. Some local authorities in United States are planning to outlaw transport and infrastructure development in vulnerable coastal areas.

2.2.1.4 Life cycle costing

Costing is a key factor in deciding the adaptation measures. How safe and strong should be the infrastructure and at what cost? There are limited research in costing and life cycle costing of adaptation measures in transport sector (Agrawala and Fankhauser 2008). Ozbay et al. (2004) have analyzed the application of life cycle cost analysis in highway agencies in US and found implementation gaps, mistrust between theory and knowledge and its implementation. It was mainly applied in road pavement but not extensively for other road structure.

A climate risk screening and management approach called Opportunities and Risks of Climate Change and Disasters (ORCHID) methodology has been developed by the Institute of Development Studies (Tanner et al. 2007). They argue that the methodology helps development organizations and their partners to integrate risk reduction and adaptation processes into their programmes. They have implemented pilot projects in India and Bangladesh. In one of the transport project in Bangladesh the study have evaluated options of raising road embankment height from 0.5 to 1.0 m to protect the road from flood and found that it was an economically viable option.

Multilateral institutions have just started to begun to integrate adaptation concern in their programmes but it has not yet penetrated the policy makers. One of the important aspects of adaptation is to streamline responses to climate change policy in development planning (Burton and van Aalast 2004; MDBs 2007). 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). Mills and Andrey (2002) also acknowledged the gap in understanding climate change impacts, adaptation and its costs. Bouwer and Aerts (2006) looked at the financing options and suggest that climate adaption should be seen as general risk management issues and linking “climate proofing” of development projects to management practice in national sectors and multilateral donors as a viable option. Srinivasan (2006) argued adaptation must be considered in an intergraded manner locally, nationally and internationally by mainstreaming adaptation concerns in development planning and policy.

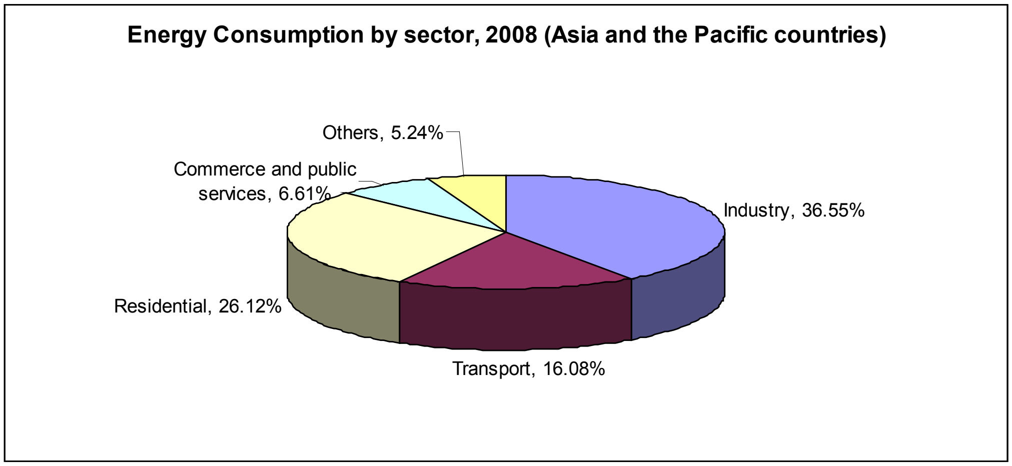
2.2.2 Mitigation

Mitigation refers to implementing policies to reduce greenhouse gas emissions and enhance sinks (IPCC, 2007). Many mitigation initiatives and measures in the transport sector focus on the issues of passengers and urban transport. These include emission reduction potential through modal shift from private mode to public transport and mass transit systems, demand management through congestion charging, improvement of vehicle efficiency, and use of non-fossil fuels. Guidelines and publications relating to passenger, urban and road transport are readily available (Dalkmann and Branigann 2007, ADB 2006).

2.2.2.1 Energy use in the transport sector

The transport sector is the third largest consumer of energy and the largest consumer of petroleum product in the Asia and the Pacific region. Energy consumption in the transport sector is growing faster than that of other sectors and other regions, driven by a rapid increase in motorization and strong transport demand from economic development. The global energy use in the transport sector is expected to increase by 50% by 2030 (IEA 2009a). Within the transport sector of the Asia and the Pacific region, road transport consumes about 80% of petroleum products whereas the share of rail is just 2%. Evidently, road is the heavily favoured transport mode in Asia for both passengers as well as freight.

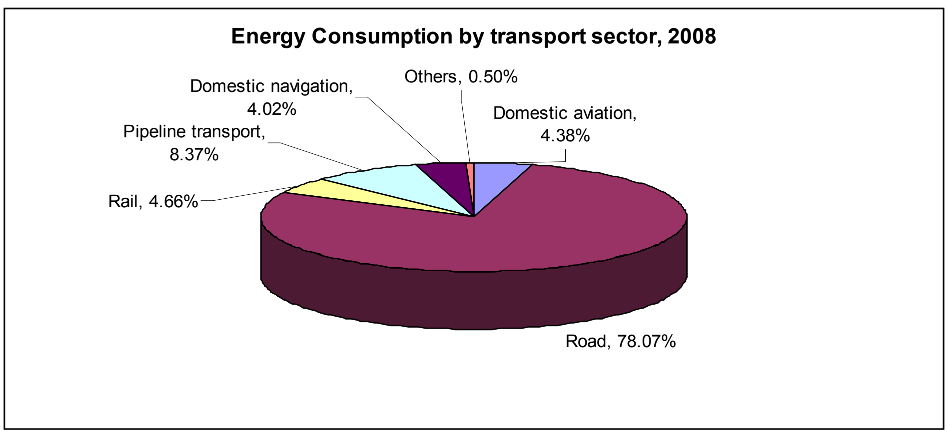
Figure 2.1 illustrates energy consumption in Asia and the Pacific region by sector (IEA 2010a) and shows that the transport is the third largest consumer of energy after industrial and residential consumption.



Source: IEA, 2010a

Figure 2.1 Energy consumption by sector in Asia and the Pacific

Figure 2.2 further illustrates energy consumption by the transport sector (IEA 2010b) and clearly shows that the road transport subsector consumes 436.2 million tonnes of oil equivalent or about 78% of the consumption of the transport sector. This is followed by pipe transport with an 8.37%, whereas the share of rail subsector is only 4.66%.

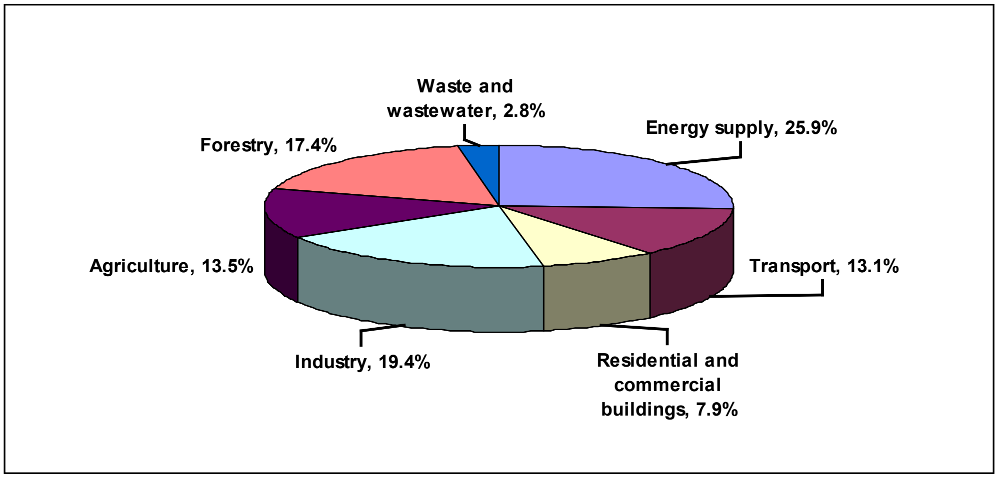


Source: IEA, 2010b

Figure 2.2 Energy consumption by transport sector

2.2.2.2 Transport sector emissions

Figure 2.3 illustrates the contribution of various sectors to global greenhouse gas (GHG) emissions and shows that the transport sector accounts for 13.1% of total world emissions (IPCC 2007).

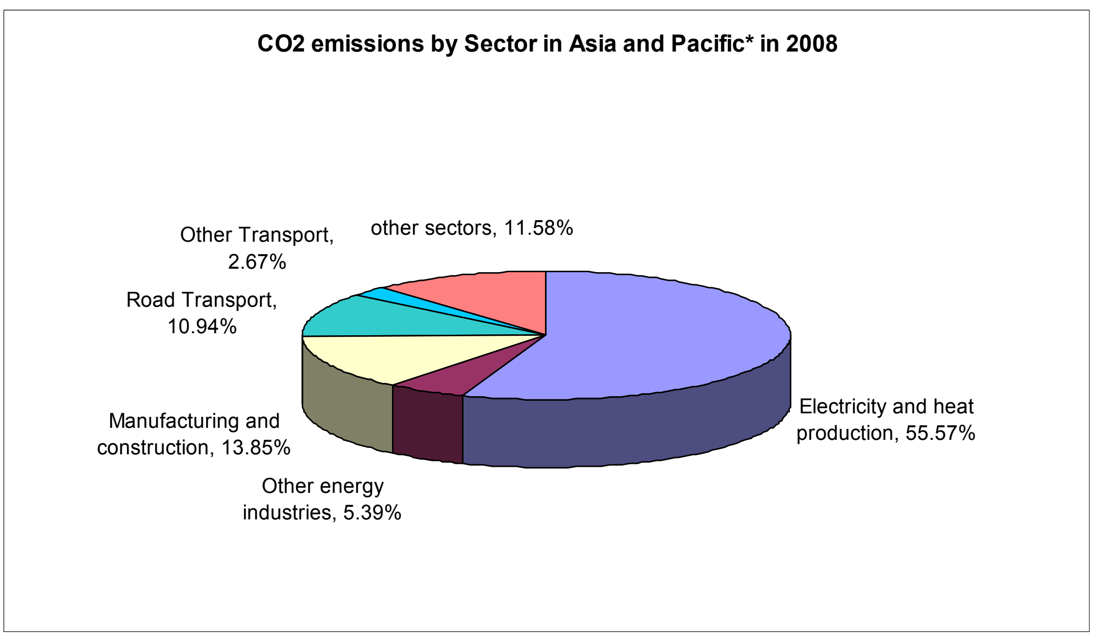


Source: IPCC, 2007

Figure 2.3 Global GHG emissions by sector

Globally, CO_2 accounts for 75% of the total GHG emissions, of which the transport sector accounts for 23% (IEA 2009b). Road transport accounts for 75% of transport CO_2 emissions, whereas the share of rail and shipping is 12.5% and that of aviation is 12.5% (Stern 2007).

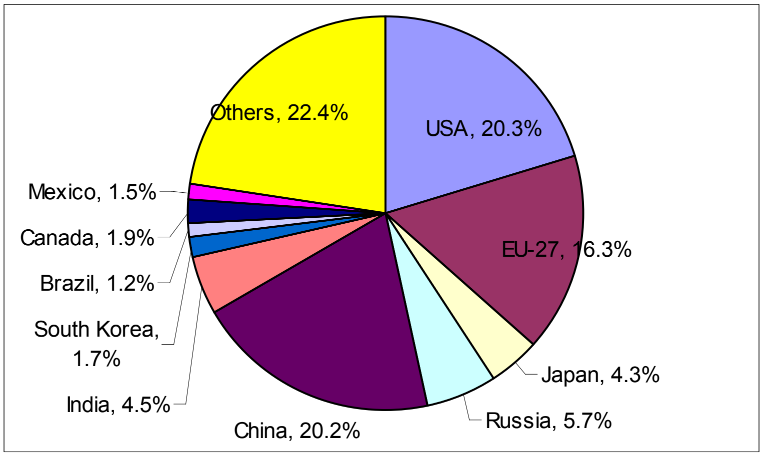
Figure 2.4 shows that in the Asia and the Pacific region CO_2 emissions from the transport sector were 1,587.4 million tons, of which 1,275.8 millions ton or more than 80% was from road transport. The transport sector ranked third in term of CO_2 emission and accounted for 13.6% of total emission, road transport alone accounting for almost 11% of the total emissions (IEA 2010b).



Source: IEA, 2010b

Figure 2.4 CO_2 emission by sector Asia and the Pacific

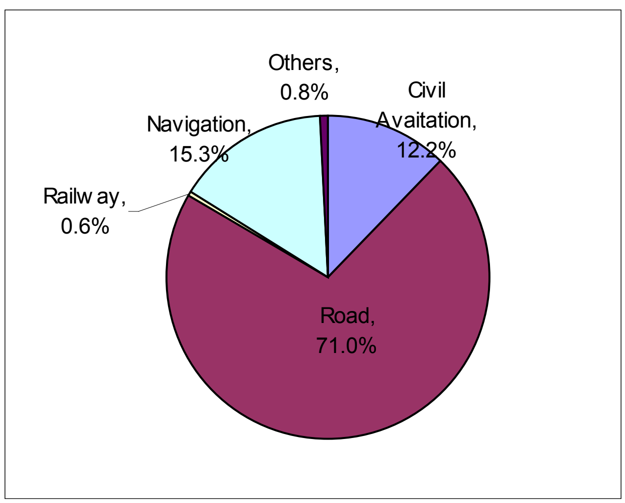
Figure 2.5 shows CO_2 emissions by countries, which clearly shows that US has highest share of CO_2 emissions followed by China. EU share of emission is 16.3%. Major industrialized Asian countries China, India, Japan, and South Korea collectively accounts for 30.7% of CO_2 emissions (EC 2009).



Source: EC, 2009

Figure 2.5 CO_2 emissions by countries

Figure 2.6 shows CO_2 emission by mode in EU which clearly shows that the road transport accounts for 71% of CO_2 emissions while railway has insignificant 0.6% share. This mode share clearly shows that policies and measures for emission reduction should be focused on road transport, if the transport sector has to contribute to the global GHG reduction.

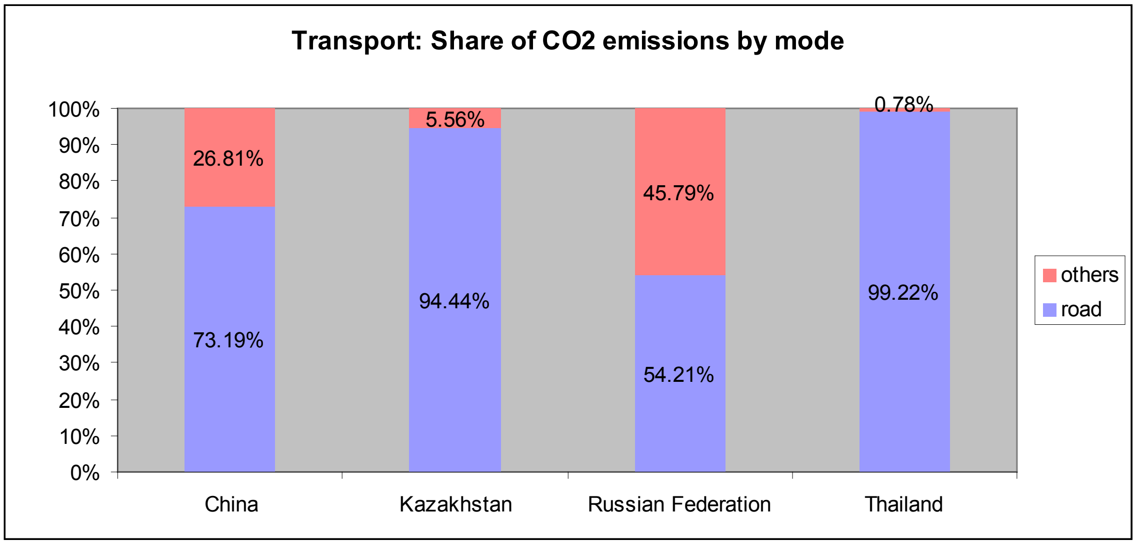


Source: EC, 2009

Figure 2.6 CO_2 emissions by modes in EU

While in aggregate, 80% of the region's CO_2 emissions from the transport sector originate in the road subsector, this percentage varies from country to country, depending upon the importance of each mode of transport in the overall transport task.

Figure 2.7 illustrates that the road subsector in Thailand and Kazakhstan accounted for more than 90% of total CO_2 emission generated from road transport activities, whereas road transport activities in China and the Russian Federation generated 73% and 54% of total CO_2 emission of transport sector respectively in 2008 (IEA 2010b).



Source: IEA, 2010b

Figure 2.7 Transport share of emissions by modes

Among transport sector, the road transport consumes large share of energy and has highest share of emissions both for passenger and freight. Therefore, the focus of policy interventions and actions should be targeted on reducing energy use and emissions from road transport. One of the key policy challenges for sustainable transport development therefore would be to increase the modal share of "greener" modes of transport from road to railways and inland waterways through the increased use of multimodal transport.

2.2.2.3 Emissions measurement

Measurement of transport emissions is necessary to plan and implement policy measures. An accurate emissions measurement can facilitate monitoring and assessment of emissions including CO_2. It can be useful in planning sustainable transport policies, develop and implement appropriate climate change mitigation measures, and enhance international cooperation. Development and use of standard assessment methods for CO_2 emissions can also help the assessment of achievement and make possible for comparison among countries.

There are many existing models available to measure emissions such as: US Environmental Protection Agency's Mobile and MOVES; European Environment Agency's COPERT 4; International Vehicle Emission (IVE) Model; and International Energy Agency's Mobility Model (MoMo). ADB's Excel sheets are some frequently used models. Review of some emission models used in countries can be found in OECD (2002). Recently developed emission model Changer (IRF 2009) can estimate total carbon footprint of road construction, maintenance, and rehabilitation.

However, there are several data gaps in Asia. Most of the emissions data referred to are from developed countries OECD, European Environment Agency (EEA), and IEA. It is difficult to find vehicle activity data; therefore, initiatives are required to collect and collate emissions data in Asia.

(i) Top-down and bottom-up approaches

The emission factors are usually aggregated and averaged over a large number of driving cycles and due to the method employed to estimate emissions factors and disaggregation of emissions they may not reflect emissions of vehicles driven under actual conditions.

The emission factors estimation are based on either 'top-down' or 'bottom-up' approaches. In the top-down approach, total annual road traffic emissions are disaggregated first spatially and then temporally over the area, using traffic load and speed variation in a dimensionless form. In the bottom-up approach, emissions are calculated on the basis of the available traffic patterns and then summated. Emissions are calculated for each street or road of the area under simulation, and on an hourly basis. The patterns of traffic flow, and the variation of average speed with time, should be used to calculate the temporal variation in emissions. This means that traffic counts and speed measurements (or estimates) should be available for the modelled area. Clearly, the bottom-up approach attempts to simulate reality more accurately, and requires more effort than the top-down method, although it is not yet clear whether such a degree of sophistication results in more reliable emission estimates, and consequently better air quality simulations (EEA 2009).

In principle, the top-down and bottom-up estimates of motor vehicle emissions are carried out independently. In each case the most reliable information (such as traffic counts, statistics of vehicle registrations and measured emission factors) form the basis of the calculation.

Bottom up approach is useful to calculate emissions for specific conditions and vehicle type that can be aggregated. Bottom-up approach provides more clue than top-down, and can provide more information to policy makers to assess driving force behind the increasing emissions. However, the bottom-up approach needs more and reliable data that can be compared with top-down estimates (Kumari et al. 2005, Ravindra et al. 2006)

Bottom-up focuses on technology and their characteristics, while top-down focuses more on process within economy of energy system and historical behavior. Bottom-up approach is suited to evaluate policy instruments and both top-down and bottom-up approaches are comparable for transport sector (van Vuuren et al. 2009, Hoogwijk et al. 2010).

For measuring emissions from road transport EMEP/EEA Guidebook (EEA 2009) recommends using Tier 2 or Tier 3 methods. These are usually called bottom-up approach. While Tier 1, which uses average emissions factors and fuel sold or consumed is referred at top-down approach. IPCC guideline also recommends using Tier 1 and Tier 2 for carbon emissions.

(ii) IPCC Tier 1, Tier 2 and Tier 3 methodologies

Vehicle emissions can be estimated using different approaches and accuracies. Various methodologies to be used for measuring emissions are outlined IPCC Guidelines (IPCC 2006). Countries follow the prescribed method to report national emission to the United Nations Framework Convention on Climate Change (UNFCCC). Depending on degree of accuracy required three Tier approach is used. The level of complexity also increases with Tier. CO_2 emissions are best calculated on the basis of amount and type of fuel combusted and its carbon content.

The 'Tier 1' approach is a simple method to calculate CO_2 emissions by multiplying estimated fuel sold with a default emission factor. The general Tier 1 equation for CO_2 emissions from road transport is:

$$\text{Emission} = \Sigma\,[\text{Fuel}_a \times \text{EF}_a] \tag{2.1}$$

Where:
Emission = Emission of CO_2 in (kg),
Fuel_a = fuel sold (TJ);
EF_a = emission factor (kg/TJ)
a = type of fuel (petrol, diesel, natural gas, LPG etc)

Tier 2 approach is similar to Tier 1 but the default emission factors should be replaced by country-specific carbon contents of the fuel sold in road transport are used. The Tier 2 approach considers the fuel used by different vehicle categories and their emission standards. Equation (2.1) can be used for Tier 2 method as well.

Methodologies for estimation of emissions from railway locomotives are similar for three Tiers and they only have variation of the same equation:

$$\text{Emissions}=\Sigma(\text{Fuel}_{j*}\times\text{EF}_j\,) \tag{2.2}$$

Where,
Emissions = emissions (kg),
Fuel_j = fuel type j consumed (as presented by fuel sold) in TJ
EF_j = emission factor for fuel type j (kg/TJ),
j = fuel type (diesel, gas oil).

For Tier 1, emissions are estimated using a fuel-specific default emissions factor, assuming that for each fuel type the total fuel is consumed by a single locomotive type. Tier 2 uses the same equation with country-specific data on carbon content of the fuel.

Tier 3 is more detailed than Tier 2 methodology based on activity data and emission factor but with a greater disaggregation of activity data and emission factors. When a more accurate estimation of the relevant emissions is required Tier 3 methodology is used. It considers hot and cold start emissions as well as different driving situations like urban, rural and highways. However, for CO_2 emission measurement IPCC Guidelines recommends using only Tier 1 and Tier 2 methodologies and for railways there is no advantage of using Tier 3 methodology (Eggleston et al. 2006).

EMEP/EEA Guidebook (EEA 2009) provides a different equation containing number of vehicles and annual distance travelled:

$$E_{i,j} = \Sigma \left(N_{j,k} \times M_{j,k} \times EF_{i,j,k}\right) \qquad (2.3)$$

Where,
$E_{i,j}$= Emissions
$EF_{i,j,k}$ = technology-specific emission factor of pollutant *i* for vehicle category *j* and technology *k* [g/veh-km],
$M_{j,k}$ = average annual distance driven per vehicle of category j and technology k [km/veh],
$N_{j,k}$ =number of vehicles in nation's fleet of category j and technology k.

Schipper et al. (2009) outlines simple activity based approach called ASIF to calculate emissions.

$$G = A * S * I * F \qquad (2.4)$$

Where,
G= carbon emissions from transport
A= Total activity (passenger or freight travel)
S= Modal structure (travel by mode)
I=Modal energy intensity
F=Carbon content of fuel.

(iii) Framework for measuring freight emissions

Most of the above vehicle emission models are centered on emission factors and fuel consumption for particular type of vehicles. The emission factor considered is also aggregated and averaged at national level which may differ from actual field condition. All these models give figures for comparisons which at cases may be far less than actual emissions. There is a wide variation in value of emission factors depending on the source being used. Fuel consumption also may not take account of air conditioning, lights used during driving etc. At time the estimates could understate the emissions by 25% (OECD 2002).

Therefore, it is proposed to measure emission by combining Equations (2.1) and (2.2) to estimate total emission from road vehicle and rail as they will be using different fuel compositions. This approach is similar to the emission measurement approach taken by Schipper et al. (2009). The combined equation is:

$$\text{Emissions} = \Sigma \left(\text{Fuel}_{i,j} \times EF_{i,j}\right) \qquad (2.5)$$

Where,
Where, '*i*' is total fuel type consumed by vehicle '*j*"

Introducing an average vehicle kilometer and number of vehicle, the equation (2.5) can be written for a land transport corridor,

$$Emissions = \Sigma FV_j * VTKm_j * EFR_{i,j} + \Sigma FT_j * TTKm_j * EFT_{i,j} \quad (2.6)$$

FV_j – Number of freight trucks
$VTKm_j$ - Average vehicle Ton-km travelled
$EFR_{i,j}$ =emission factor of fuel i for vehicle j (g/veh-km)
FT_j = Number freight Train,
$TTKm_j$ = Average train Ton-km travelled,
$EFT_{i,j}$=emission factor of fuel i for locomotive t (g/train-km).

(iv) Emission factors

The emission equations require emission factors for emission estimation. Vehicle emissions largely depend on type of vehicle, engine capacity, speed, actual driving pattern, condition of road, load factor etc. In case of train, it depends on engine capacity and traction used whether it is electric, diesel or coals driven, load factor, speed, and track condition. These data are aggregated and averaged. Variation on emission factors are found based on different sources. There are many data and research available in IEA countries. IEA used top-down approach for emission calculation. Table 2.1 presents CO_2 emission factors complied for LDV, HGV and freight trains (DEFRA 2009).

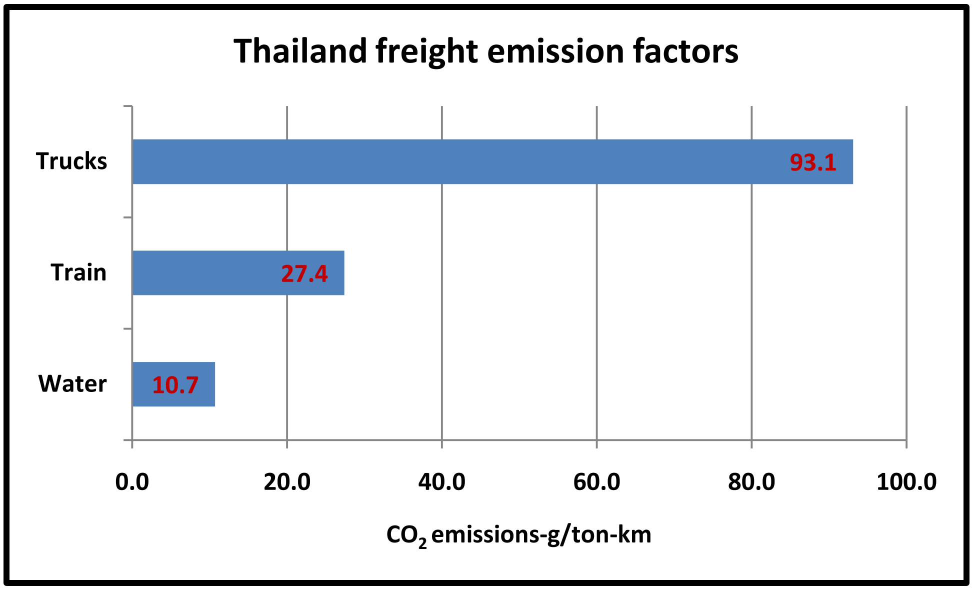
Table 2.1 Emission factors of various transport modes

Mode	**Emission Factor gm/ton-km**
Road LGV	400.1
HGV	118.6
Rail	28.3
Small tanker	20
Large container	13

Source: DEFRA, 2009

IPCC Guidelines suggest that CO_2 emission factors should be within a range of $\pm$5%. It is good practice to ensure that default emission factors reflect local fuel quality and composition.

Figure 2.8 illustrates the emissions factors of various modes of transport in Thailand. It clearly shows that water and railway transport are far less polluting than road transport. Therefore, in order to have net environmental benefits, we need to explore ways and means to encourage modal shifts to more less polluting or environmentally friendly modes.



Source: Derived from Chamroon, 2011

Figure 2.8 Emission factors for transport modes

(v) Studies on measurement of transport emissions

Woodburn et al. (2008) suggest interventions such as policy, regulation and infrastructure development for model shift many opportunities to improve efficiency and environmental impacts of international road and rail freight transport. Buehler et al. (2008) looked at ways to stimulate environmental friendly behavior through used of inland container depot (ICD) and dry ports and concluded that potential to reduce CO_2 emission through model shift is limited in Germany. Bauer et al. (2009) claim that CIRRELT was first to address environmental issues in freight transport and distribution planning model utilized minimization approach, scheduling and application to rail network, container based transport, intermodal nodes and links. The role of energy efficient vehicle technology was discussed and predicts 30-50% emissions reduction possible in 20-40 yrs through improved engine, weight and drag reduction, hybrid technology, reduce demand and integrated planning (Heywood 2008).

The MOVE software developed in US claims to be best tools for GHG emissions can handle multi-scale analysis, policy analysis, and requirement to assess emission and develop state implementation plan. Transport sector use 35% of total energy in Thailand and 76% of transport energy consumed by road sector indicating high dependence on road sector and suggest expansion of rail freight transport as one of the policy option (World Bank and NESDB 2009).

A methodology for evaluating environmental impacts of railway freight transportation policies was developed and used in Leon-Gijon railway line in Spain and revealed that bottom-up analysis gives good result (Lopez et al. 2009). Freight transport in UK has been analyzed. One study looked at expert's opinion on the environmental impact of road freight in the UK in 2020 using the Delphi techniques and concluded that the transport grew faster than GDP during 1995-2005 and forecasted that freight is expected to grow at slower pace (Piecyk and McKinnon 2006, McKinnon and Piecyk 2009).

Kamakate and Schipper (2009) used bottom-up approach to compare energy intensity of truck freight in selected developed countries and focus on road freight transport by light and heavy truck. Similar earlier studies revealed that growth of emissions from trucking and that there is a little opportunity for a major shift from trucking to rail. Wang et al. (2008) used the bottom-up methodology to estimate vehicle emissions for the Beijing urban area combining vehicle emission factors, vehicle activity data, and vehicle emission using a travel demand model. Woodburn (2003) looked at logistics perspective of freight mode shift from road to rail in Great Britain.

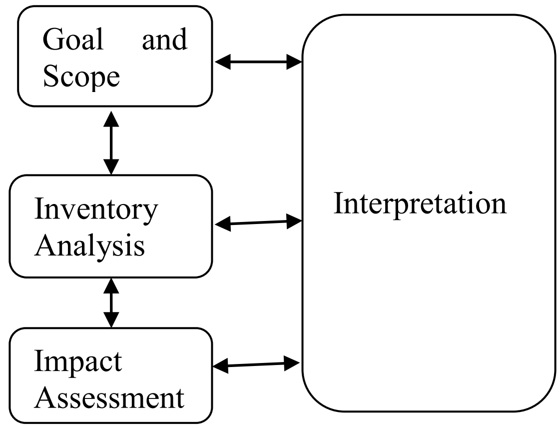
McCollum and Yang (2009) looked at 80-50 emission reduction potential in US discussed Silver Bullet Scenario and argued that not a single mitigation option can meet GHG goal. They outlined that a combination of technology, public transport, vehicle efficiency were major areas for CO_2 reduction. Tsamboulas et al. (2007) analyzed potential of mode shift, sensitivity analysis, and policy action plan, applied it to two corridors in Europe and suggested that railway liberalization, increasing efficiency of terminals and rail speed were some of the policies for action plan. Van Essen (2009) analyzed modal shift and decoupling transport growth from GDP for freight transport and proposed infrastructure policy, improving interconnectivity and pricing were major policy that can influence a modal shift. Timilsina and Shrestha (2009) analyzed trends of energy use in Asian context applying decomposition analysis. De Jong et al. (2004) reviewed freight transport models and suggested approaches for future development of fast system dynamics model for policy analysis and detailed network-based freight transport model with interlinked modules.

(vi) Life cycle assessment

The above methods give estimates at a point of time or yearly based on activity. However, while developing infrastructure usually the assessment of emission over its life cycle is assessed. It can then be compared to see whether there are any environmental benefits of developing such facilities.

There are many definition of life cycle assessment (LCA). It comprises a systematic evaluation of environmental impacts arising from the provision of a product or service (Hunt et al. 2009). LCA is a "cradle to grave' assessment tool for products or processes (Mundy and Livesey 2004). ISO: 1997 defines LCA as "*compilation of product system throughout its life cycle*."

An ISO 14040 and 14044 standard recommends using four interdependent phases as shown in Figure 2.9 while carrying out LCA. They are: (i) scope and definition; (ii) inventory analysis; (iii) impact assessment; and (iv) interpretation.



Source: ISO: 14040, 2006

Figure 2.9 Phases of life cycle assessment

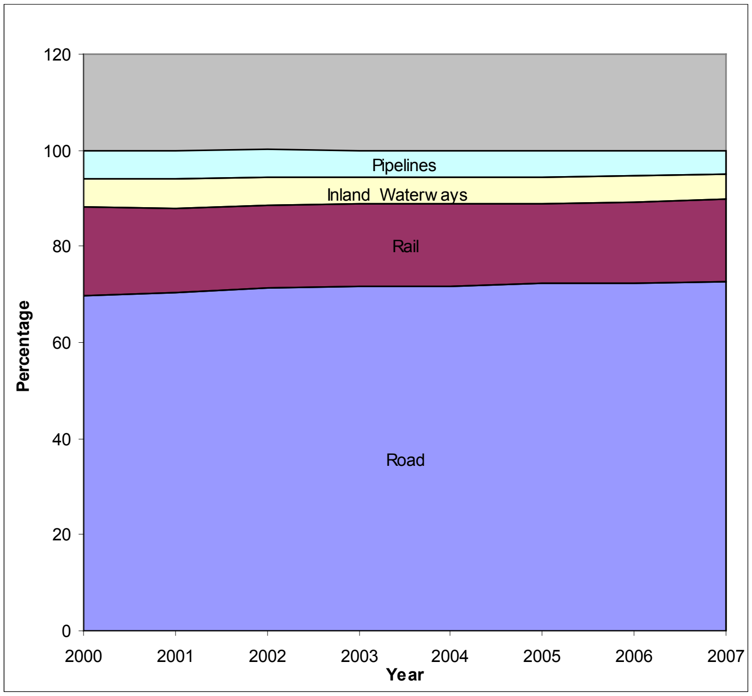
Utilizing process based LCA CO_2 emissions of transport infrastructure and related infrastructure can be estimated. For an O-D pair for freight movement in order to influence modal shift the infrastructure needs have to be determined. Basically this involves civil infrastructure related to road, rail, bridges and dry ports construction. The LCA approach can evaluate construction related CO_2 emission due to infrastructure development.

Chang and Kendel (2011) have used similar LCA approach for high speed rail construction in California. The emission factors of various construction activities can be found in literature and guidelines (Kato et al. 2005, Akerman 2011). Guideline and code of practice for life cycle assessment have been developed by the Society of Environmental Toxicology and Chemistry and United Nations Environment Programme's life cycle initiatives (UNEP 2011). Institute for Transport Policy Studies (ITPS) and Japan Railway Construction Plc have analyzed effect of railway development from the view point of environment. Ministry of Land Infrastructure and Transport (MLIT), Japan has developed summery report of the survey on transport related energy consumption in Japan. LCA was used in South Korea to analyze LCA of energy consumption and GHG emission in transport sector using input-output table (Phirada et al. 2010).

The system boundary and activities for LCA is first defined and then life cycle inventory analysis is carried out to estimate the quantity of various types of infrastructure development such as length of road, railway, size of dry ports, and length of bridges. The ideal way of doing LCA is to cover material production, material transport and equipment used for construction of transport linkages. Other approach used is input-output method to evaluate various components.

2.2.2.4 Freight mode share

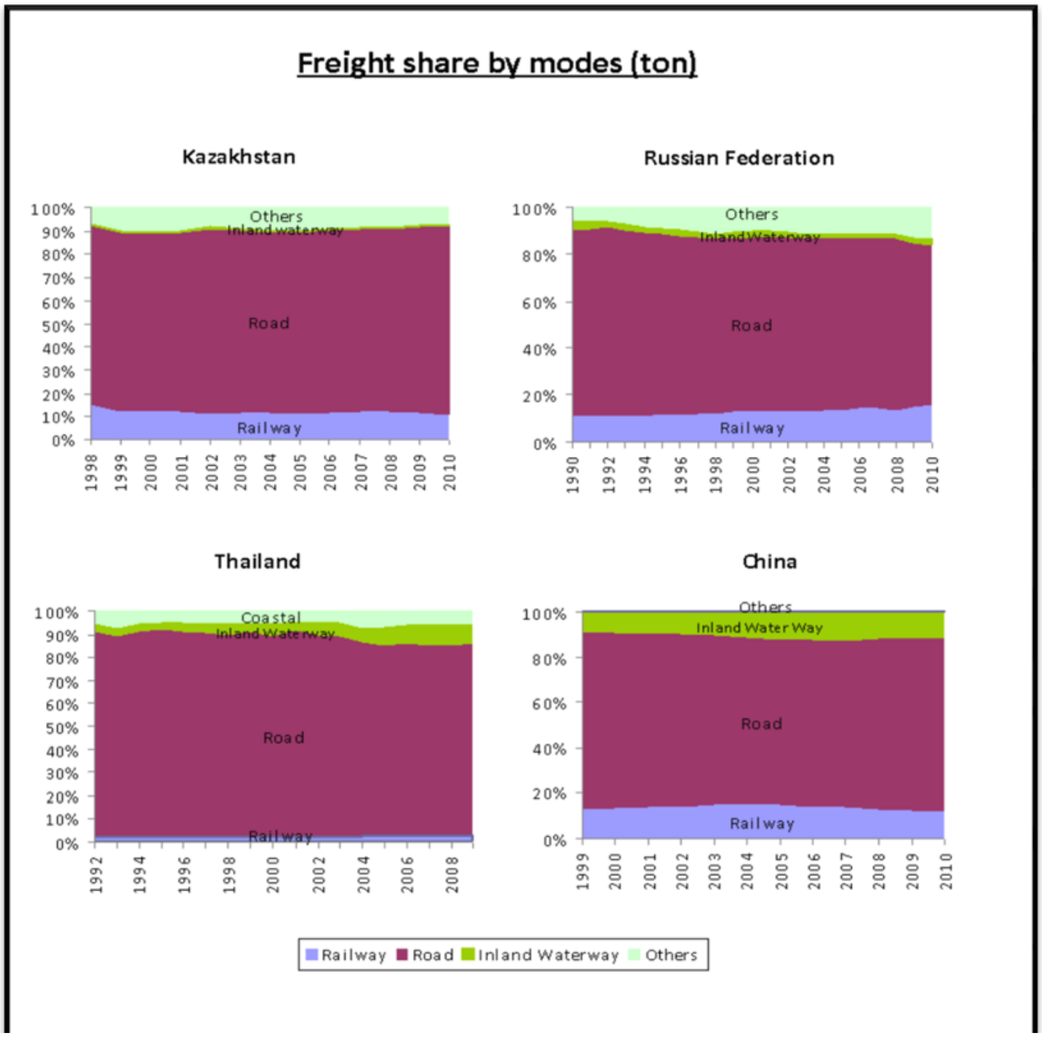
Figure 2.10 shows the freight modal split of inland transport in EU. The road has more than two-thirds of freight mode share. In EU countries overall tonne-km increased by 34% between 1997 and 2007. During the same period road freight increased by 43%, air freight 31% and maritime transport grew by 10% (EEA 2010). The growth in road sector is outpacing other sector. Freight transport activity in tonne-km is expected to nearly double by 2020.



Source: EEA, 2010

Figure 2.10 Freight modal split of inland transport in EU

Similarly, Figure 2.11 illustrates the freight modal split of selected Asian countries and indicates that road transport has a major share of total tonnes of freight carried in these countries. The figure also shows a slight growth of freight carried by railways in the Russian Federation and by inland waterways in China, the Russian Federation and Thailand. For Thailand in 2009 the freight mode share of road transport has 84% share and water transport (inland and coastal) 14% and train about 2%.

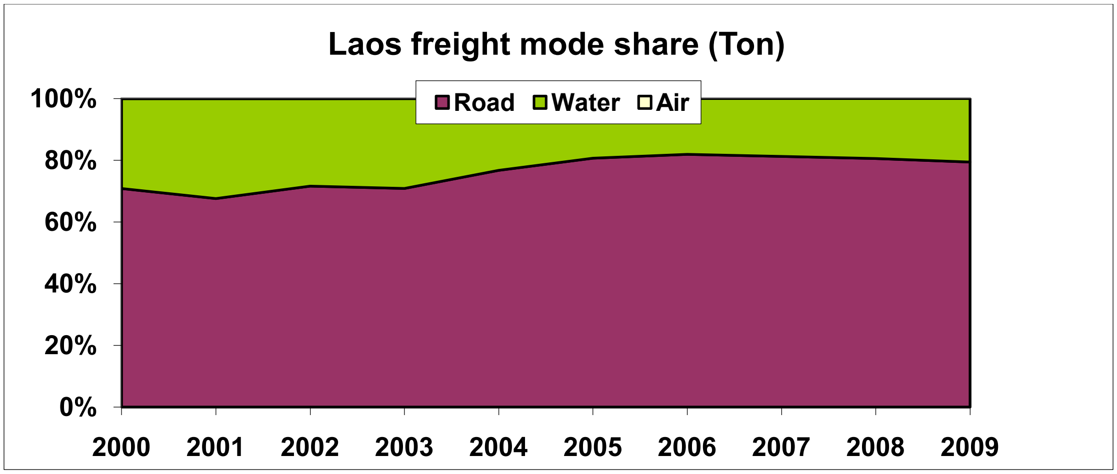


Source: CEIC 2010 and ECE 2010

Figure 2.11 Freight modal split for selected Asian countries

However, if freight transportation is considered in tonne-kilometres, total freight in China was 11,030 billion tonne-km in 2009, of which highways accounted for 30%, railway 21% and water transport 47% While in India total freight was 1,410 billion tonne-kilometres in fiscal year 2007/8, of which road accounted for 50%, railway 36% and water transport 6% (Dayal 2011).

Figure 2.12 shows the freight mode share in Laos which shows that road transport has 79.5% share and water transport 20.5% and air transport has negligible share (CEIC 2010).



Source: CEIC, 2010

Figure 2.12 Laos freight mode share

In case of Japan also the freight mode share heavily favoures road transport with share of 61%, while maritime 34.8%, railway 4%, and air transport 0.2% (JFRC 2009).

As road mode share is more than other modes in all situation, one of the key policy challenges would be to increase the mode share of non-road transport modes such as railways and waterways which are more environmentally friendly and energy efficient than road transport. Woodburn et al. (2007) have analyzed scope of mode shift in UK through fiscal and regulatory measures.

2.3 Intermodal transport

Intermodal transport refers to the movement of goods in one and the same loading unit or road vehicle, which uses successively two or more modes of transport without handling the goods themselves in changing modes (ECE 2001). Intermodal transport is also defined as the use of at least two different modes of transport in an integrated manner in a door-to-door transport chain (OECD 2001).

Intraregional exports and imports are increasing throughout Asia. Exports and imports grew by over 15% year-over-year from 2007 to 2008 (ESCAP 2009b). Asia's share of world containerized exports and imports are expected to rise to 68% and 56%, respectively, by 2015. The total number of containers handled in Asian ports is estimated to reach 492 million twenty-foot equivalent units (TEU) by 2015, and the transshipment volume will comprise 109 million TEU of this total (ESCAP 2007). The growth of intraregional trade and the expected growth of containerized transport in Asia clearly demonstrate the need for improved intermodal freight transport in the region.

Earlier models of transport development have adopted a unimodal approach in which road and rail projects were planned and constructed separately without much consideration for their possible future integration. Intermodal transport uses more than one mode of transport and delivery of goods from origin to destination. Such transport has been studied in detail by policymakers and transport planners, who are undertaking various policy initiatives to promote the concept and implementation of intermodal transport. The development of intermodal transport requires the consideration of three of its attributes: transport links, transport nodes, and the provision of efficient services. The following section provides further details on the development of transport link, nodes and services in Asia.

2.3.1 Transport links

In order to promote intermodal transport, it is essential to improve transport links such as highways, railways, and inland waterways. In Asia, there has been good development of transport networks such as Asian Highway and Trans-Asian Railway (ESCAP 2003 and 2006). The Master Plan on ASEAN Connectivity (ASEAN 2010), which includes the Singapore-Kunming Rail Link and other transport corridors, is an example of the attention that national governments are giving to the transport links. Asia includes major countries like China, India and the Russian Federation, which have extensive railway and highway network; however there is a need to construct missing links of railways to provide uninterrupted railway connectivity in these countries. Further, roads and highways also need to be constructed and upgraded to higher standards to improve highway connectivity. In addition, certain highways and railways routes lack capacity and maintenance therefore considerable investment has to be made for regular and periodic maintenance if they are to provide efficient services.

Railway was first invented to carry freight, and they now run on clean form of energy (Smith 2003). The energy intensity and long life cycle of rail cars, along with new innovations that offer increased speed, have put railways in a competitive position to take a major share of the growing transport demand in terms of both freight and passengers. Efforts by policy makers and railway operators are needed, though, necessary to maintain railway's environmental superiority among other modes of transport. The common factors likely to influence consumer's choice of transport mode choice are relative cost, time and reliability, and for passenger service, the degree of comfort.

Other important issue related to international railway transport is break-off-gauge. Railway tracks in many Asian countries have been developed using different track gauges, for instance, 1,676 mm, 1,520 mm, 1,435 mm, 1,067 mm and 1,000 mm. Different gauges at borders of countries prevent rolling-stock from passing through and create the need for goods to be transferred across these borders in a separate operation. These operations include manual or mechanical transshipment of goods from wagons of one gauge to wagons of different gauge, the change of bogies, and the use of "variable-gauge" wagons (ESCAP 2011a).

2.3.2 Transport nodes

Transport nodes such as airports, seaports, logistics intermodal terminals, and dry ports need to be developed in order to promote intermodal transport. From among these, seaports have developed rapidly in Asia, as evidenced by the fact that 19 of the top 30 container ports in the world are located in Asia (CI 2010). Inland dry ports are also important transport nodes, particularly for landlocked countries. The development of these dry ports in inland area far from seaports can promote intermodal transport, and provide intermodal transfer opportunities to change a mode. These facilities also offer transshipment, temporary storage and distribution services. Another important service the dry ports should offer is customs clearance facilities where traders can clear their goods and cargoes near their business.

2.3.3 Transport services

Intermodal transport requires improvement in the efficiency of transport services. The logistic performance index (LPI), which indicates the quality of trade, transport, and services, varies widely among Asian countries. For example, Asian courtiers with high LPI for 2010 include Singapore (4.09), Japan (3.97), South Korea (3.64), and Thailand (3.29) while Laos (2.46), Mongolia (2.25), Afghanistan (2.24), Nepal (2.2) and most landlocked countries had a low LPI (Arvis et al. 2010).

Road transport, which is the most flexible transport modes, is usually operated and managed by the private sector, and in certain limited cases, by the public sector. Most railway route operations in Asia are still handled by public sector railway companies under overall government control. Quality is the single most significant problem in railways freight operations. In order to attract greater share of freight, the quality and reliability of service must be improved, and the punctuality of freight service must be maintained. This requires both a reform of existing railway operation systems and new approaches to railway marketing. Ballis and Golias (2002) have examined ways of improving efficiency of railroad terminals. If private-sector freight forwarders can provide quality services, public sector railway companies would also be able to improve their services. Service quality and price are important factors in encouraging a modal shift (Buehler et al. 2005).

In order provide door-to-door service, railways must be integrated with existing logistical networks. Interfaces between railways and other transport modes are essential in order to encourage a modal shift. It has been suggested that government can help increase rail freight share by developing rail freight as a business, encouraging a level playing field as well as private sector involvement and competition, and reducing barriers of borders (Amos 2009).

2.4 Development of dry ports

The development of dry ports, as an integral part of the intermodal transport and logistics chain, provides opportunities for international trade by facilitating export and import of goods to/from inland locations. It can also bring social and economic development to the surrounding areas by attracting value added services and industries like freight forwarding, transportation, packaging, customs agent and others related services. The dry port can also support local industries by facilitating their access to markets, and distribution.

While there have been efforts in Asia to develop regional highways, railways, and seaports, inland dry ports are at an early stage of development. Therefore, efforts are required to extend the reach of intermodal transport to the inland area and landlocked countries through development of dry ports. Through connection with various modes of transport it can promote intermodal transport and mode shift to energy efficient modes and contribute to the overall goal of emission reduction.

In addition, these dry ports have potential for attracting manufacturing and distribution facilities; and economic stimulus for regional economic development. Furthermore, special economic zones and free trade areas that provide special tax incentives are also being created adjacent to dry port locations.

ESCAP has recognized the importance of dry port locations and suggests that the following criteria are important when deciding upon a location: (a) inland capitals, provincial/state capitals; (b) existing and potential industrial and agriculture centers; (c) major intersections of railways, highways, and inland waterways; and (d) intersections along trunk railways lines, major highways, inland waterway, and at airport (ESCAP 2010a).

There are two type of approaches for the development of dry ports one is initiating a new dry port to create its own market and service base and the other is servicing the existing demand of a market. The third type could be upgrading of existing dry port in terms of increasing capacity, improving efficiency and adding services and connectivity. Following section outlines definitions, function and benefits of a dry port in more detail.

2.4.1 Definition and functions

A dry port is an inland terminal which is directly linked to a maritime port (ECE 2001). There are various terms used interchangeably to refer dry ports such as inland ports, inland container depots, inland clearance depot, inland freight terminal, freight village, intermodal freight terminal etc. Notteboom and Rodrigue (2009) provide several definitions relating to dry ports, inland transfer points, and inland terminals. ESCAP publication on logistics sector development (United Nations 2007) also includes various terminology and definition used and comprehensive information on functions and framework for development of dry ports. ESCAP (2011b) uses the term "dry port of international importance" and defines it as a “secure inland location for handling, temporary storage, inspection and customs clearance of freight moving in international trade.”

The main function of dry port is to bring facilities offered by ports to inland areas. The most important requirements of dry ports are: (i) connectivity to a seaport; (ii) customs clearance service offered; (iii) security of cargoes; and (iv) facilitation of international trade. Rodrigue et al. (2009) stipulate following three fundamental characteristics related to an inland dry port:

- (i) An intermodal terminal, either rail or barge
- (ii) A connection with a port terminal through rail, barge or truck services, often through a high capacity corridor.
- (iii) An array of logistical activities that support and organize freight transited.

In addition Rodrigue et al. (2009) also state that dry ports service three major functions within supply value chain (i) satellite terminal; (ii) fright distribution clusters or load centres; and (iii) intermodal transshipment facility.

Dry port should provide range of functions, facilities and services to the customers. Some of the key functions and services required at a dry port are outlined in Table 2.2.

Table 2.2 Functions and services required at a dry port

S. No.	Type	Function and service
1	Transport and logistics functions	• Handling and dispatch of cargos and containers • Temporary storage of empty or laden containers • Temporary storage or warehousing of cargoes • Consolidation and deconsolidation • Transshipment of freight and cargoes
2	International port functions	• Customs inspection and clearance • Issuance of bill of lading • Functions related to international trade
3	Information Technology functions	• Information systems linking customs/sea ports/customers/service providers to facilitate transport
4	Other value added service to the customers and drivers	• Freight forwarding • Customs brokerage • Security • Banking • Repairing and maintenance of vehicle and containers • Packaging • Sanitation • Medicine and emergency.

Source: ESCAP 2010d

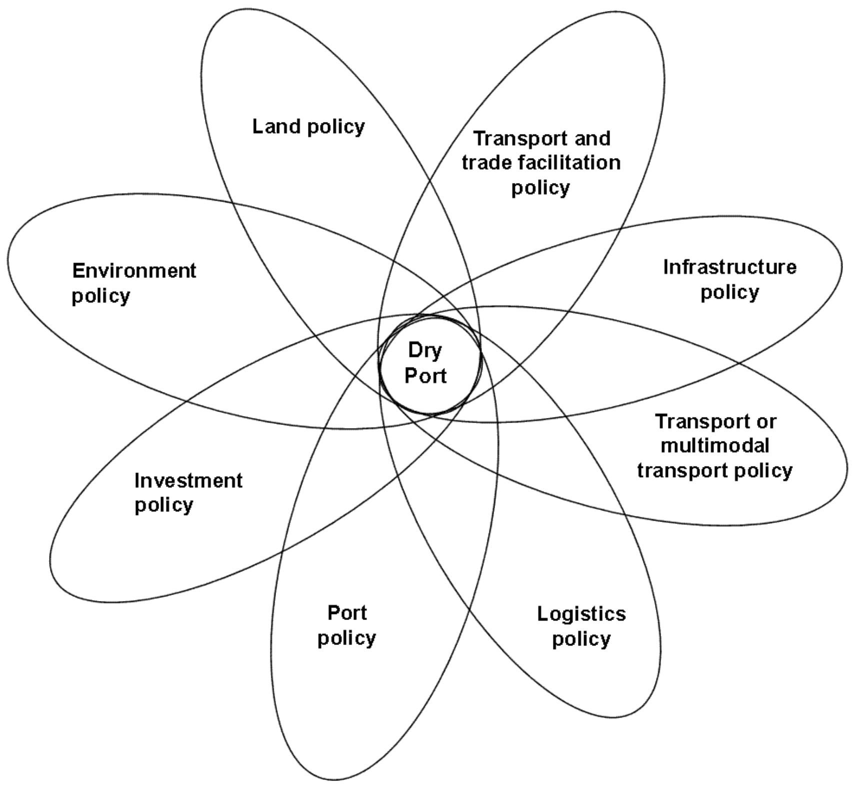
In order to provide services to the customers, dry ports should have infrastructure, equipment and facilities capable of handling existing cargoes and future demand. These largely depend on the capacity of dry ports and function envisaged, the following list provide guidance on these (ESCAP 2011b).

(i) Secured area with gate and separate entrance and exit;
(ii) Covered and open storage areas separated for import, export, transshipment, dangerous and high value cargoes;
(iii) Customs bonded facilities;
(iv) Internal service roads and pavement for use in the operational and stacking area;
(v) Vehicle holding areas with adequate parking space for freight vehicles;
(vi) Container, vehicle and equipment repair and maintenance workshop;
(vii) Administrative building for customs, freight forwarders, shippers, customs brokers, banks, and agencies;
(viii) Information and communication systems and services; and
(ix) Appropriate numbers of cargo and container handling equipment.

There is no standard classification of dry ports. They can be classified based on the mode served, capacity, and location. Roso et al. (2009) suggested classifying dry ports based on distance from ports namely: close, midrange and distant dry port. Once the dry port is established and service is provided continuous efforts should be made to improve operational efficiency of the dry ports, streamline clearance procedures, increase reliability of transportation service between seaport and the dry ports. These are very important aspects as in some developing countries in Asia the logistics costs amounts to 10-20% of GDP.

2.4.2 Policies related to dry ports

Dry ports are a key component of the intermodal transport. Existing government policies and regulations relating to dry ports influence their development and operation. Figure 2.13 shows the links between dry ports and various sectoral policies that may be relevant to the development of dry port (ESCAP, 2010b).



Source: ESCAP, 2010b

Figure 2.13 Policies and regulations relevant to dry ports

Different institutions are involved in development and operation of dry ports. The various policies shown in Figure 2.13 are those affiliated with various sector and ministries. For example, overall infrastructure development policy is related to the ministry of planning, investment policy is related to the ministry of finance, while trade facilitation policy is related to ministry of trade and commerce, and transport and logistics policy is related to the ministry of transport. In addition, different levels of government-central, provincial, and local – will also have different policies relating to the dry port development. For these reasons, coordination among various sectors and different levels of the government is essential during development and operation. Designation of lead or coordinating agency and thus providing potential developers of dry port projects with "one stop" services and advice, including all necessary government approvals, license, during planning, development and operation will facilitate the developments of dry ports. Further, special economic zones and free trade areas that provide special tax incentives are also being designated adjacent to dry port locations to provide economic stimulus.

During operation in addition to the logistics services usually provided by the private sector the related government agencies should arrange for necessary inspection and clearance. For example a representative of customs for customs clearance, trade for export and import clearance and security are necessary. Policy frameworks would be necessary in order to improve efficiency and services at the dry ports. Some of the measures could be integrating transport modes, ensuring better coordination among various agencies, designating a lead agency, setting up performance and operational standards, pricing policy, policy on investment such as public private partnerships, built-operate transfer, lease concession policy, streamlining procedure and documentation required for clearance, export and import, subsidies to environmental friendly modes to promote a modal shift, and enhancing safety and security.

2.4.3 Benefits of dry port development

The development of dry ports offers three types of benefits: transport and logistics benefits; economic and social benefits; and environmental benefits. First and foremost, benefits of dry ports are the trade facilitation, customs clearance for medium business at door step rather than having to go to the seaports for clearance. It also contributes to the economic and social development of the surrounding area by bringing new opportunities for employment generation and business. It is often seen that the area near dry ports are developed as special economic zones, free trade areas and production and manufacturing centres. The dry ports make it easier for business to trade and transport goods. These production and manufacturing centres generate cargoes for the dry ports that again generate employment opportunities and further business. Thus, it creates a virtuous business cycle that attracts further investment and business to the area.

Door to door to service, customs clearance near business, value added service, opportunities for consolidation of low volume cargoes, providing business for local trucks, mini trucks and vans for distribution, and employment opportunity are list of few benefits. Dry ports can extend the capacities of ports, reduce pollution, help to share cost of infrastructure, and provide additional space for seaports.

Dry ports, where various modes of transport meet, can offers opportunities to encourage modal shift from one mode to another. In order to receive net environmental benefits of intermodal transport, measures that will encourage shift to more environmentally friendly mode are necessary. The planning and development of freight terminals, freight villages, dry ports, ICDs can extend the reach of the rail mode through intermodal services. Rail-based intermodal freight transport is more environmental friendly than truck-only, particularly for long-distance haulage in terms of CO_2 emissions and other pollutants produced by long-distance hauling (Kim and Wee 2009). Railway is considered an ideal mode of connection between seaports and dry ports (Roso et al. 2009).

There are plenty of empirical evidences of environmental benefits of dry port development some of which are outlined in the following paragraphs.

Construction of consolidation centers/dry ports near strategic urban locations can also help reduce the number of freight trips. One example of this is the Freight Construction Consolidation Center in London. Established to consolidate construction freights and minimize construction traffic for building and development, it has resulted in fewer freight trucks and a 75% reduction in CO_2 emissions (TfL 2007).

Thus location of dry port and freight hubs is an important consideration. When analyzing intermodal transport and location of dry ports or freight hubs, many studies have considered the potential environmental impacts to be an important factor for analysis (Lv and Li 2009, Wei et al. 2009). The implementation of a dry port concept in Sweden, in which freight transported from seaport and dry port by truck was replaced by railway transport, led to as much as a 25% reduction in CO_2 emissions as well as reduced port congestion (Roso 2007).

Activity-based emissions modeling of and intermodal transfer point in north Taiwan compared distribution by intermodal transport using coastal shipping and trucks to distribution by trucks alone. The results indicated that the efficiency of coastal shipping led to 60% less emissions (Liao et al. 2009). Other study showed greater reduction in CO_2 when transshipment routes are changed from the established ports to emerging port of Taipei (Liao et al. 2010). A study of freight emissions in London revealed that consolidation and distribution centers have combined 25.7% reduction in emissions **(**Zanni and Bristow 2009). Freight and consolidation centers/dry ports have also potential to reduce the empty truck trips. For example, 12-30% of trucks run empty in Pakistan and 43% run empty in China (Londono-Kent 2009). Improved logistical organization, coordination, and route planning could reduce CO_2 emissions by as much as 10-20% worldwide (OECD 2010).

The promotion and development of intermodal transport and a modal shift to rail transport can help to reduce CO_2 emissions and other pollutants. Freight carried by rail emits much less CO_2 compared to freight being transported by heavy good vehicle (HGV). In the UK, the average CO_2 emission per ton/km is 28.3 g for rail freight, 118.6 g for HGV, and 400 g for light goods vehicles in UK (DEFRA 2009). Hanaoka et al. (2011) measured energy savings by intermodal freight transport in Thailand and found that it would be possible to save 25% energy by using intermodal transport.

Dry ports that are established near manufacturing and distribution facilities can offer positive environmental benefits due to the reduced travel distance for manufacturing goods that are distributed through dry ports and raw material that are transported to factories.

It is not always that dry port would only bring positive benefits. There are bound to be some adverse environmental impacts may relate to noise, pollution, and congestion. However, it will also contribute to local economic development and trade.

In some instances, dry ports may induce more cargoes by improving efficiency of transport services, thus truck haulage are possible to be increased which might also increase the possibility of growth truck hauling that increases both noise and the emission of pollutants such as CO, NOx, SO_2, volatile organic compounds (VOCs) and hydrocarbons that contribute to local air pollution. The noise and vibrations generated by freight vehicles, and the operation of handling equipment, may also be a nuisance to locals living in the area. The quality of fuel used by transport modes and vehicle congestion on roads as well as at dry ports can have additional environmental impacts. Therefore, consideration should be given to the utilization of cleaner and greener forms of fuel/energy in transport and to the improvement of the operational efficiency of transport services and dry ports by adopting an integrated and holistic approach. Environmental impact assessment undertaken for the development and operation of dry ports should consider all potential impacts and develop a mitigation plan for likely impacts, including emissions of pollutants, noise, and vibrations. Although we must clearly understand that inland intermodal freight transport cannot be made emissions-free, efforts should nonetheless be directed toward making intermodal transport more sustainable.

2.4.4 Contribution of dry ports to emissions mitigation

From the examples presented above, the environmental benefits of the development of dry ports can be seen. They can be categorized as (i) reducing road congestion; (ii) reducing number of empty truck trips; (iii) increasing load factors; (iv) reducing pollution; (v) improving operational efficiency; and (vi) reducing emissions. As one of the primary characteristics of inland dry port is to have high capacity rail and/or inland waterways connection to the seaports, the resulting mode shift further contributes to the emissions reduction.

However, it should be noted that the development of dry port itself is not sufficient condition to affect a modal shift. For these to happen, many policy initiatives are required to make the railway or inland waterway more attractive. This also highly depends on the frequency of services offered, transportation cost and total transportation time. Streamlining clearance and inspection procedure, reducing number of documents required for clearance are also important considerations to improve overall efficiency of whole logistics chain. Mainly the responsibility of facilitating these rests with the government. As Asia is still in early stage of dry port development learning through experiences and bring good practices from other region would help to continuous improve the process. Although not comprehensive, the following actions would be required for a change of mode to happen.

- (i) Efficient railway connection to sea ports
- (ii) Reliability and frequency of service
- (iii) Competitive dry port use price and delivery time compared to other modes
- (iv) Customs clearance facilities
- (v) Use of information and communication service (ICT) such as electronic data interchange (EDI), radio frequency identification (RFID) geographic information system (GIS) to improve efficiency and provide information to the customers
- (vi) Security of cargoes, containers, personnel at dry ports
- (vii) Quality of service;
- (viii) Provision of other value added service to the customers.

2.4.5 Dry port location problem

There are many factors that need to be considered while planning and developing dry ports. Lack of clear policies and institutional arrangements, conflicting interest of stakeholders pose greater problem in selecting location of an inland dry port.

Some of the common factors that affect the location of dry ports are its proximity to ports, markets and manufacturing area, connections to other modes of transport, costs of development, operation and transport, potential of encouraging mode shift, environmental concerns, security, and existing government policies. While some of established cost benefit analysis (CBA), environmental impact assessment (EIA) can look at economic, financial and environmentally feasibility that can compare potential alternatives. However, as many of the above factors are subjective and cannot be quantified, that makes the location problem a complex.

The dry ports location problem can be analyzed by using multi-criteria decision analysis (MCDA). Analytic Hierarchy Process (AHP) and Analytic Network Process (ANP) are well recognized methodologies to analyze multi-criteria decision problem. The methodology consists of defining a problem with a set of evaluation criteria and sub criteria, assigning relative weight for each criteria and evaluating alternatives location. This method can compare and rank possible alternatives. The AHP/ANP model could help decision makers to evaluate various alternatives and make decision based on their preferences. Lee (1998) has used AHP for appraisal of transport projects in South Korea. AHP and ANP were applied for environmental impacts assessment and evaluation of transport policies (Islam and Saaty 2010, Berrittella and Certa 2007, Brozova and Žika 2010). Yang and Kuo (2003) used AHP and DEA for analyzing facility location problems.

Blauwens et al. (2006) suggests that a combination of policies can lead to modal shift and it can occur if the shipper's logistical requirements are fulfilled and fit in their logistical chain. Jarzemsks and Vasiliauskas (2007) have analyzed the case of Baltic Sea Region through a survey to know perception of shippers and industries perspective on dry port concept. Bontekoning et al. (2004) have reviewed many studies based on search and concluded that there is a need to look at modal split in routes. Baird (2005) compared existing hubs with new and competing hub locations in order to optimize the container transshipment hub location in northern Europe. Dadvar et al. (2010) looked at the feasibility of dry ports in Iran used a survey and Strength-Weakness-Opportunities-Threats (SWOT) analysis.

Arnold et al. (2003) have developed binary location model considering road and rail mode, continental freight taking a case of Spain and Portugal. Multi-criteria decision analysis methodology was used to evaluate transport projects such as ports and terminal in Brussels focusing on stakeholder analysis (Macharis et al. 2004). An optimal location model was developed and used to evaluate intermodal terminals in Europe using reliability, flexibility and cost criteria (Moreira et al. 1998). Gursoy (2010) analyzed, rail-road sea mode using AHP in Turkey considering shipping price, time for transportation mode choice.

Macharis (2001) developed decision support system PROMETHEE, using multi-criteria decision analysis, location of inland water terminals in Belgian situation, and ranking of alternative using LAMBIT model. Ng and Gajur (2009) surveyed 26 firms to look at the dualist policies of government, rent seeking behavior, and questioned whether dry ports are consumer oriented? Wang and Meng (2010) used Monte Carlo simulation to estimate port market share in China and South Asia. Falzarano et al. (2007) developed Geospatial Intermodal Freight Transportation (GIFT) model to evaluate energy, environmental, operating cost and time trade off and elaborate a case of route selection of New York-Jacksonville that included intermodal transfer node, road-rail, and road-waterway, rail-waterway connections.

2.5 Multi-criteria decision analysis

MCDA has been extensively used to analyze problems that involve many stakeholders' views and considers many factors including those involving location problems. MCDA was used to evaluate alternative options for environmentally sustainable transport system in Delhi (Yedla and Shrestha 2003) and assessment of transport projects (Tsamboulas et al. 1999). AHP and Analytic Network Process (ANP) were used to study and evaluate potential location of logistics centers/inland ports in China (Wang and Wei 2009, Wei et al. 2010), freight village in Greece (Kapros et al. 2005) and intermodal transshipment and hub ports in Turkey (Önüt and Soner 2008, Onut et al. 2010 and Tuzkaya et. al. 2008). AHP was used to analyze location of wind observation station (Aras et al. 2004), to measure performance of intermodal transport in Thailand (Hanaoka and Kunadhamraks 2009), infrastructure management (Smith and Tighe 2006), appraisal of transport projects in South Korea (Lee 1998), and prioritization of pavement maintenance activities (Farhan and Fwa 2009, Cafiso et al. 2002). An agent based model was developed to analyze location of inland ports and hubs in Australia (Sirikijpanichkul 2007).

Ho and Dey (2010) have extensively reviewed the use of MCDA methods and found that combination of AHP-GP and DEA were the most applied MCDA approaches. Methodology employing the use of AHP, ANP and AHP-GP were used (Lee 1998, De Montis et al. 2000, Tanadtang 2004, Firouzabadi 2005). ANP and fuzzy logic were also used to analyze location problems. However, Saaty (1995) argued that ANP and fuzzy-logic adds to the complexity of the problem and calculations however the final output compared with AHP is similar. Firouzabadi et al. (2008) used MCDA to select design and manufacturing alternatives employing combined AHP-GP approach. Sattayaprasert (2008) used AHP and ANP to analyzed transportation of hazardous material in Thailand.

Therefore, from literature, it can be seen that the location problem can be analyzed by utilizing MCDA approach. The decision problem involves consideration of various factors and views of various stakeholders that include government decision makers as well private sector transport service providers. AHP one of the MCDA methodologies (Saaty 1997) can incorporate feedback of various stakeholders and utilizes this in prioritizing and ranking alternatives. The subjective as well as objective criteria and sub-criteria that are relevant to the problem at hand can be incorporated in AHP. AHP has been widely used for planning and resource allocation, prioritization of alternatives- which is the problem at hand (Saaty 1995). As many criteria and preferences could be conflicting- a set of solutions with ranking could be presented to the policy makers to assist in the decision making process.

2.5.1 Analytic hierarchy process

AHP can consider both quantitative and qualitative criteria and derive relative weights and prioritize alternate locations based on evaluation criteria selected. The AHP has been extensively used for location analysis and prioritization of alternative. Facility location of inland ports in the United States was analyzed with objective of minimizing vehicle-miles travelled and promoting regional freight transport (Rahimi et al. 2008). Wu et al. (2007) applied AHP for analysis of hospital location in Taiwan, Ozdagoglu and Ozdagoglu (2007) used linguistic evaluation to compare MCDA methods, Park et al. (2009) used AHP to evaluate air cargo express service of the carriers and Reza et al. (2011) applied AHP based life cycle assessment to evaluate flooring system. AHP was used to prioritize transport projects (Shelton and Medina 2009), to select railway station site in Iran (Mohajeri and Amin 2010) and to select port in Nigeria (Ugboma et al. 2006).

Using a systematic hierarchy structure, complex estimation criteria can be clearly and precisely represented (Saaty 2004). The AHP involves the following process:

(i) Hierarchy development- defining goal, evaluation criteria and sub-criteria and alternatives;
(ii) Pair-wise comparison of criteria, sub-criteria and alternatives;
(iii) Weight derivation of criteria, sub-criteria and alternatives;
(iv) Synthesis- derivation of priorities; and
(v) Consistency check.

2.5.2 Location analysis using AHP

The facility location problem needs to be decomposed into levels of hierarchy consisting of one goal, evaluation criteria, sub-criteria, and alternative locations. The criteria and sub-criteria need to be further refined after consultation with the related officials. The alternatives selected should be the location of real logistics centers proposed for development. This decomposition of decision problem makes it possible to judge the importance of the elements in a given level with respect to other elements in the same level. The number of main criteria and sub-criteria has to be not more than six in order to limit numbers of questions for pair-wise comparisons and to increase probability of receiving feedback on the survey. AHP assumes the criteria and sub-criteria should be independent of each other.

Sipahi (2010) and Tubucanon and Lee (1995) have extensively reviewed the application of AHP in research and transport sectors. Appendix-I includes various criteria and sub-criteria used by other researches for location analysis of dry ports. Relevant criteria and sub-criteria can be selected after reviewing the elements considered by earlier studies (Wang and Wei 2009, Wei et al. 2010, Kapros et al. 2005, Önüt and Soner 2008, Onut and Saglam 2008, Tuzkaya et al. 2008, Aras, et al. 2004, Mohajeri and Amin 2010, Ugboma et al. 2006, Guneri et al. 2009, Kahraman et al. 2003).

2.5.3 Multi-objective decision making

Some studies have also used multiobjective optimization approach (Racunica and Wynter 2005, Macharis 2001) and considered minimization of time and costs. Rahimi et al. (2008) looked at location allocation of ports and inland ports- with objective to minimize vehicle-miles travelled (VMT) and promotion of regional freight transport utilizing the concept of facility location. Sirikijpanichkul et al. (2007) have analyzed location of inland ports and hubs in Australia and developed an agent based model.

Ballis and Golias (2002) considered terminal design parameters, terminal capacity, and layout, number of equipments, tracks, stacking policy, and technology. Kim et al. (2009) analyzed trade-off between CO_2 emissions and logistics costs based on multiobjective optimization of hub and spoke system for Rotterdam and Gdansk (Poland) port and evaluated various six scenarios. Limbourg and Jourquin (2009) studied rail road terminals locations while analyzing efficiency of sustainable transport and concluded that it depend on location of container terminals. Masui and Yurimoto (2000) used input-output analysis and revealed that a 48% potential for reduction in road emission which is the largest producer of NO_x.

Ng and Gajur (2009) analyzed the spatial characteristics of inland transport hubs in Southern India. They used mixed integer programming based on cross-sectional data to look at performance, efficiency, competitiveness, container truck only and truck and train considering Cochin and Tuticorin ports, Coimbatore and Tirpur ICD/dry ports.

Onut et al. (2010) used fuzzy ANP-based approach for ports selection to evaluate seven alternative ports and concluded that Istanbul district was convenient in Marmara Region, Turkey. Pedersen (2005) developed optimization models and solution methods for intermodal transportation. Preston and Kozan (2001) developed an approach to determine storage locations of containers at seaports terminals. Optimal location model of intermodal freight hub to look at the increasing share of rail, hub and spoke system was used (Racunica and Wynter 2005). Wisetjindawat (2010) discussed all options of freight modal shift presenting various cases of modal shift in European countries including water, coastal shipping and rail-environmental friendly modes. The example included freight villages, consolidation centres and underground freight system being developed in the Netherlands.

2.5.4 Goal programming

Goal programming (GP) is a part of mutli-objective decision making. Contrary to economic analysis which usually considers single objective such as utility or profit maximization or cost minimization, GP can consider multi-objective problems. This is common problem with decision makers who are confronted with multiple and simultaneous objectives. GP attempts to minimize the deviations from the goals and determines the point that satisfies the set of goals in a decision problem (Schniederjans 1995, Schniederjans et al. 1982). Each objective is transformed to goals with addition of deviation variables and specifying the most desirable value as the aspiration goal (Jones and Tamiz 2010). In generalized term, the goal programming formulation is given by equation (2.7):

$$f_i(x) + d_i^- - d_i^+ = a_i \quad \text{(for } i = 1, 2 \ldots\ldots\ldots n\text{)} \tag{2.7}$$

Where $d_i^-, d_i^+ >= 0$

d_i^-, d_i^+ are negative and positive deviation variables
x= decision variable
a_i is the aspiration level of the goal or target.

GP always consist of two types of variables decision variables and deviation variables. The objective function of the GP is always minimization of deviation variables. There are various approaches to solve the location problem; weighted GP is commonly used to solve the multiobjective decision problem. The weighted GP's objective is to find a solution that minimizes the weighted sum of goal deviations as shown in equation 2.8. The overachievement and underachievement of goals are undesirable.

Combined AHP-GP model can help decision makers to make proper decisions satisfying overall requirements of policy maker's priority and can consider budget and other constraints. AHP output weights are used as input to GP. The combined model utilizes policy maker's perspectives/ preferences in addition to the location attributes-that considers costs, budget, freight demand and using the coefficient and output of the AHP model makes combined AHP-GP model more robust (Tu et al. 2010).

$$MinZ = \sum_{g=1}^{G}\sum_{i=1}^{m} w_{g,i}\left(d_i^- + d_i^+\right) \tag{2.8}$$

$$s.t. \sum_{j=1}^{n} a_{i,j} X_j + d_i^- - d_i^+ = b_i \tag{2.9}$$

Where,
$w_{g,i}$- weight of goal g,
$a_{i,j}$ -coefficient of decision variables (from AHP output)
X_j-decision variable, location of dry port
$d^{+/-}$ positive and negative deviational variables
b_i target value or goal of a criteria

The GP objective functions can be developed for the each criterion used to evaluate the location and reformulated as constraints adding deviational variables. These objectives can be expressed as minimization of development and operation costs, transportation time, and environmental impacts and maximization of intermodal transport connectivity and regional economic development. Other constraints relating to capacities of proposed dry ports, freight demand, cost of development of dry ports and available budget can also be used. Finally, as the location problem is a binary (0, 1) whether it is selected or not and a constraint in the GP model can also be added to ensure at least one dry port site is selected. Badri (1999) had combined AHP and Goal-Programming to analyze global facility location problem. Yang et al. (2010) have applied AHP-GP to analyze intermodal freight transport from China to Indian Ocean.

2.6 Mode choice

The mode choice depends on the utility value of mode for the individual or company making choice. There are two components of utility the systematic utility which can be measured to some extent and a random utility component (Ortuzar and Willumsen 2001). Comparing the measured utility value of one transport mode with other mode the decision to select a mode is made. This is illustrated by following utility functions (Ben-Akiva and Lerman 1985).

$$U_i = V_i + \varepsilon_i \tag{2.10}$$

Where,

U- Utility function
V- Systematic utility
έ-random component of utility
i -number of alternatives/choices

Random utility theory stipulates that the observed inconsistencies in choice behaviour are taken to be result of observational deficiencies on part of the analyst. The individual is always assumed to select the alternatives with highest utility. However, the utility are not known to the analyst with certainty and are treated by the analyst as random variables (Manski and McFadden 1999). Macharis et al. (2011) have analyzed intermodal terminals and mode choice variables. In our case as road and railway are considered options and the attributes are time, cost and reliability of road and railways.

Binary choice models can predict the probability of choosing a freight mode. The choices are associated with attributes mentioned above and utility values. Thus the probability of choosing mode 1 is the probability of that U_1 is greater than U_2:

$$P_1 = P(U_1 > U_2) \tag{2.11}$$

Where,
U_1 - is Utility of mode 1,
U_2 - is utility of mode 2.

The probability of selecting mode 1 is given by, binomial logit,

$$P(1) = \frac{\exp(V_1)}{\exp(V_1) + \exp(V_2)} \tag{2.12}$$

Where,
P(1) –the probability of selecting mode 1
V_1 - measured/observed utility of mode 1
V_2 -measured/observed utility of mode 2.

Providing map based route information to users can induce route choice, similarly provision of information on freight route, transfer facilities, costs could influence freight route choice. Field (2009) provides very clear explanation of estimation and interpretation using logistic regression through SPSS.

Soderbom (2011), Eggers (2007), and Louviere et al. (2000 and 2008) suggested ways to design choice sets. Further guidelines on choice set design have been elaborated (DOT 2002 and 2006). Samimi et al. (2011) developed truck and rail binary mode choice model and argued that there is a low level of sensitivity of fuel price which did not triggered mode shift. Kofteci et al. (2010) analyzed freight mode choice in Turkey. Fillone et al. (2006) modeled LRT in Manila using discrete choice. A mode choice model was developed and analyzed for Texas (Cambridge Systematic 2002).

2.6.1 Stated preference (SP) experiment

SP survey can seek response to hypothetical situation such as if dry port is developed, railway is connected, and frequencies of freight train service, dry ports user charges and providing them some scenarios for selection. The survey can also include other questions relating to policies, services that would be important for considering a mode shift and existing situation which is reveal preference (RP). But the RP is not be used for modeling. The attributes to be considered for mode choice are total transportation time, transportation cost (including dry port charge), and reliability (delay) of services.

Ortuzar and Rose (2010) have extensively reviewed and discussed various development and trends in designs and understandings of SP experiments and design of choice sets (DeShazo and Fermo 2002). Fowkes and Shinghal (2002) have analyzed freight mode choice in Delhi-Mumbai freight corridor in India using adaptive stated preferences method. Patterson et al. (2008) used survey of shippers and SP experiment to study intermodal services and GHG emissions in Quebec-Windsor corridor in Canada. They analyzed nine scenarios and reveled that a 20% increase in truck price was sufficient to overcome shippers' bias. Aljara and Black (1995) modeled Saudi Arabia-Bahrain corridor mode choice and Al-Ahmdi (2005) evaluated intercity mode choice in Saudi Arabia.

Caramia and Guerriero (2009) looked at modal shift towards sustainable transport modes including rail, short shipping, inland waterways, and multimodal considered a route in Italy**.** Danielis and Rotaris (1999) have reviewed SP studies and compared of RP and SP approaches. Cullinane and Toy (2000) reviewed SP literature and concluded cost, speed, transit time reliability, characteristics of goods, and service are five mostly used attributes. Garcia-Menendez and Feo-Valero (2009) have estimated binary logit model to estimate mode choice of road and short shipping in Spain considering additional attributes than cost and time. Loo (2010) studied cross-boundary container truck congestion in Shenzhen Western Corridor in Hong Kong-Pearl River Delta region using SP. Fries et al. (2008) have used combined RP and SP to develop a regional freight mode choice model in France –Nord-Pas-de-Calais. Weis et al. (2010) have developed a mode choice model in Switzerland. Train and Wilson (2008) estimated Stated-Preference experiments constructed from revealed preference choice and utilized in Columbia/Snake River System.

Dirghahayani (2009) used SP to analyze passenger mode shift to bus rapid transit system in Indonesia and used block design to present 27 choice sets as presenting all options would confuse the respondents and can take considerable time thus risking not receiving survey input. An impact of high speed rail on air transport in South Korea was analyzed using SP (Park and Ha, 2006) and found that only 14% of passengers preferred to use air transport.

Major attributes considered for freight transport SP experiment are time, cost and reliability (Garcia-Menendez et al. 2004, Cullinane and Toy 2010, Norojono and Yuang 2005, Garcia-Menendez and Feo-Valero 2009). Value of time saving was evaluated and found that time savings represented 60% of benefits generated by infrastructure investment (Alvarez et al. 2007). Feo-Valero et al. (2011a) have done extensive review of transport demand modeling and attributes to be used for mode choice models. Qualitative factors also play a significant role in the modal choice, and that their relative importance varies according to samples (Beuthe and Bouffioux 2008).

2.6.2 Application of SP experiment in mode choice

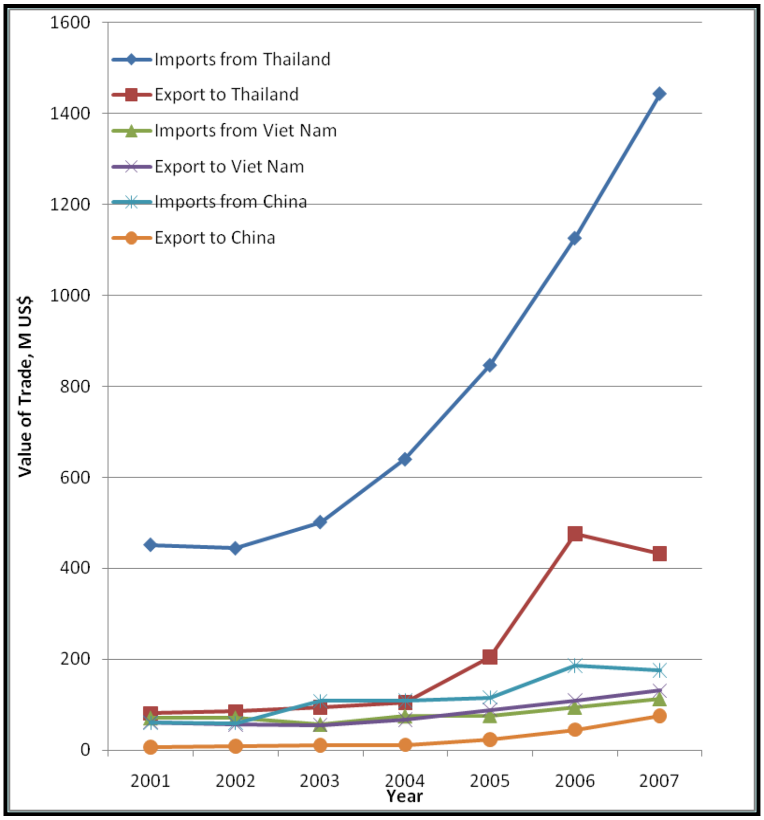
SP experiment has been extensively used for estimation of mode choice in the transport sector. For example, Shimizu and Yai (1999) have conducted SP survey and looked at the ways to reduce peak congestion in Tokyo Metropolitan Area. Feo-Valero et al. (2011b) have used SP technique using three generic variables transit time, transport cost and delivery time reliability to study mode choice of road and intermodal alternatives. Ahern and Tapley (2007) considered interurban trips in Ireland and Khan et al. (2007) developed passenger mode choice logit model for Brisbane using SP survey which is capable of estimating mode share in a mutli-modal travel environment. Feo-Valero et al. (2011b) used SP to develop mixed logit model to study mode choice between road and rail in inland leg of freight transport in Spain.

Hensher et al. (2007) provide detail explanation of use of SP considering different utility function that incorporate generic parameters as well as mode specific parameters using data from SP Greenhouse Gas Emission Survey mode choice survey in Australia. It also explains details of using NLOGIT software. McCarthy (2001) has discussed a shipper's transportation mode choice model for truck, rail and piggyback considering transportation rate, time and reliability as attributes and generic variables. Gujarati and Porter (2009) have also discussed the estimation of logit model using grouped data and provide clear interpretation of results including various measures to check the goodness of fit such as pseudo $\rho^{2,}$ and McFadden $\rho^2$and cunt ρ^2.

2.7 Case of freight transport in Laos

Laos, a land-locked country, is centrally located in the Great Mekong Subregion (GMS) within South-East Asia. It uses sea ports in Thailand and Vietnam for export and import of goods. One of the routes of the Singapore-Kunming rail project as well as the East-West GMS corridor linking Vietnam to Thailand and Myanmar also passes through Laos. Thus it has a potential to offer much needed land transport connectivity to China and Vietnam. Laos aspire to be seen as a "land-linked" rather than "land-locked" country with a vision to be a regional logistics hub in GMS. Connectivity and logistics services are also part of development agenda in GMS and Laos (Nolitha, 2011).

Laos total import and export was US $ 1,092 million (equivalent to 1.67 million tons) and US $ 2,430 million (equivalent to 1.963 million tons) in 2009 (UNCOMTRADE 2011). Figure 2.14 shows the steady growth of volume of foreign trade with its neighbors (ADB 2008b). It shows that more than 80% of its trade is with Thailand, followed by Vietnam with 13% and China with 8%. Interestingly the volume of trade with southern neighbour Cambodia is very low. Therefore, transport connection to and from Thailand is very important for Laos. Thailand is preferred to Vietnam as main transit route for Laos's imports and exports (Arnold et al. 2003).



Source: ADB, 2008b

Figure 2.14 Laos foreign trade volume

Laos is well connected by roads with Thailand. Two bridges across Mekong have already been constructed at Thanalaeng and Savannakhet. The 3rd Mekong River Bridge at Thakhek was opened recently on 11 November 2011. Currently construction of a Mekong Bridge at Huayxai is progressing and to be completed in 2012. National Highway-13 (Asian Highway-12) is the backbone of road transport. In addition to the roads there is one railway connection to Thanalaeng from Thailand. There are also plans to improve railway connectivity and feasibility studies of connection from Boten, China-Vientiane, Vientiane-Thakhek-Vietnam border are progressing (ADB 2010). The feasibility study of Boten-Vientiane Railway was completed and currently being reviewed at the time of survey. It was estimated that the construction cost would be high due to the mountainous topography and the need construct many high bridges and tunnels. Vientiane–Thakhek rail route is also in pipeline for development. Railway network in Laos is expected to expand in near future. The Mekong River is also used for water transport. The current mode share is 80% by road and 20% by water transport. However, there is no freight share currently carried by railways. ADB has estimated the freight demand for GMS to be 6.3 million tons for 2014 and 23.8 million tons for 2025 (ADB 2010).

Laos logistics performance index (LPI) is 2.46 which is better than its neighbours Myanmar (2.33) and Cambodia (2.37) while China (3.49), Thailand (3.29) and Vietnam (2.96) have higher LPI than Laos. If we compare with other landlocked countries it is better than that of Nepal (2.2), Mongolia (2.25), Bhutan (2.38) and Afghanistan (2.24). However, Kazakhstan (2.83) has higher LPI than Laos (Arvis et al. 2010).

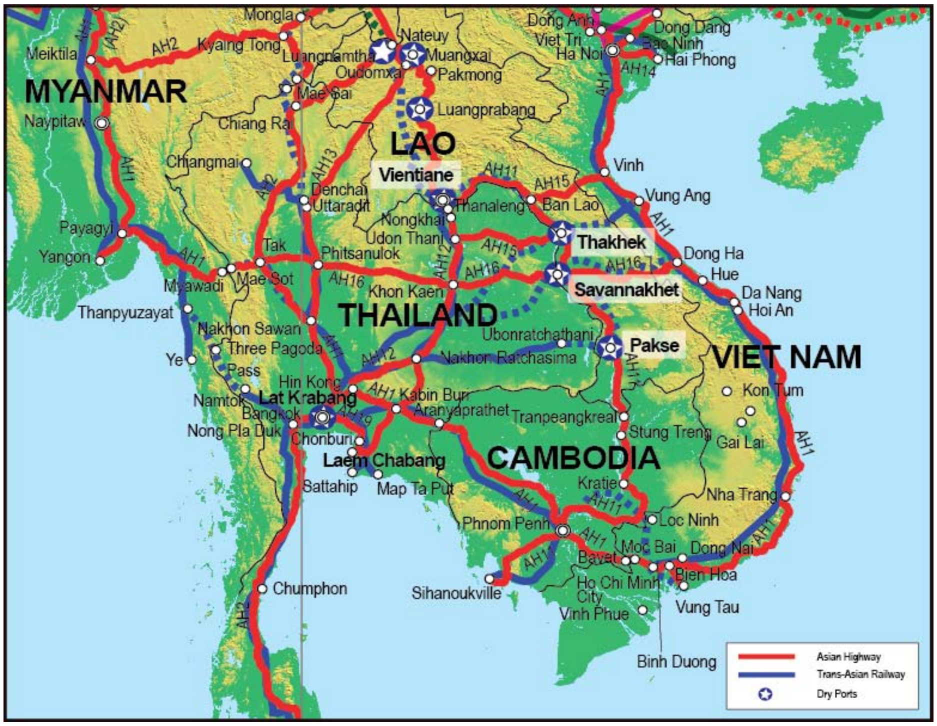


Figure 2.15 Study area and location of dry ports in Laos

Improvement of logistics system and transport connectivity would be the core activity to materialize the vision of being a land-linked country. Laos current development plan forecast a 7% growth of freight that reaches 32 million tons and 2.2 billion ton-Km by 2015 and focus on development of special economic zones already established in Boten, Bokeo and Savannakhet (MPI 2011). Thailand also has railway capacity enhancement plan that includes double tracking to Nongkhai, track rehabilitation and development of inland container depots in Nongkhai and Ubon Ratchathani near border with Laos (Mala, 2011). Laos thus can use these facilities as well as the Lat Krabang ICD near Bangkok which is connected by railway to Laem Chabang port.

Laos national strategic logistics master plan (JICA 2011) has proposed to develop three international logistics parks at Thanalaeng (Vientiane), Savannakhet and Luangnamtha and three regional logistics parks at Luangparbang, Thakhek and Phakse (Champasak) which are shown in Figure 2.15. Due to the importance of international trade, potential freight volume and transport connectivity with Thailand as well as GMS four logistics centers namely Thanalaeng, Thakhek, Savannakhet and Phakse are considered as cases in the current study. These four alternative locations have potentials to serve international and transit as well as domestic freight. The salient features of these logistics centers are shown in Table 2.3.

Table 2.3 Salient features of proposed dry ports in Laos

	Freight volume (Tons)		Design Area	Costs	Functions and roles
Dry ports	2015	2025	Sq. m	Million US$	
Thanalaeng	426,500	1,413,060	295,000	31.1	Road, rail and waterway, import and export to Thailand, limited transit to China, consolidation, transshipment and distribution
Thakhek	19,000	79,000	23,300	3.7	Road and waterway, import, export and transit to/from Thailand and Vietnam, consolidation, transshipment and distribution, bridge to Thailand near completion
Savannakhet	36,000	151,000	51,100	4.56	Road and waterway, import, export and transit to/from Thailand and Vietnam through GMS East-West Corridor, consolidation, transshipment and distribution,
Phakse	106,400	296,000	115,900	14.77	Road and waterway, import, and export to/from Thailand, transit to Cambodia, consolidation, transshipment and distribution, Storage and distribution of agricultural products

Source: JICA, 2011

Despite having logistics development plan, Laos is finding it difficult to develop these logistics facilities. Prioritization of logistics facilities would help policy makers to take decision and mobilize resources according to the priority and gradually improve overall logistics system. It is also intended to assess emissions as a result of development of dry port facility and resulting modal shift of international freight between Laos and Thailand.

2.8 Chapter summary

The review revealed that there are not many adaptation studies covering transport sector in Asia. This reinforces the need to look at sustainable transport development, climate change impacts and development of adaptation strategies in Asian context.

In terms of mitigation, it is noted that many studies and strategies focus on urban and passenger transport and not many studies covered freight transport in Asia. Therefore, there is a clear indication that this area needs to be further researched. Considering different level of energy efficiency of various transport modes –one option is to look at the potential of mode shift. As there are 12 land-locked countries in Asia, one way to look at the problem is to study extension of intermodal transport to inland area through development of dry ports which are ideally connected by railways as well as other modes of transport.

Chapter 3 further builds on this review and analyzes various methodological aspects and propose and develop an integrated research framework and methodology that considers both adaptation and mitigation. Approaches such as MCDA, AHP, Goal Programming, Stated Preference, Mode Choice Model, and CO2 Assessment are further elaborated in the context of the current research.

CHAPTER 3

RESEARCH FRAMEWORK AND METHODOLOGY

3.1 Introduction

This chapter outlines proposed framework and methodology for the research. In order to achieve the objectives of the research, an integrated methodology that incorporates four analysis modules are proposed. The methodology integrates assessment of climate change impacts, review of dry ports development, location analysis of dry ports, mode choice analysis and emission assessment. It also outlines the methodology proposed for primary data collection.

The integrated research framework enables to evaluate alternative location of dry ports and prioritize them according to the preference of stakeholders based on selected evaluation criteria. It can then assess the potential modal shift through development of dry ports based on the outcome of the stated preference survey and resulting reduction on emissions as a result of modal shift.

Initially the framework to study climate change impacts and adaptation policies in Asia is explained, followed by the Analytical Hierarchy Process (AHP) and AHP-Goal Programming (GP), development of mode choice model and bottom-up approach for emissions assessment.

3.2 Integrated methodology and analysis modules

In order to achieve the objectives of the research the proposed research framework and methodology integrates four analysis modules: (1) Adaptation policy analysis; (2) Review of dry port development and location analysis using the analytical hierarchy process (AHP) and AHP-goal programming (GP); (3) Stated preference techniques and mode choice model; and (4) CO_2 emission assessment utilizing bottom-up approach and life cycle assessment. Figure 3.1 shows the relation between the research objectives and proposed analysis modules.

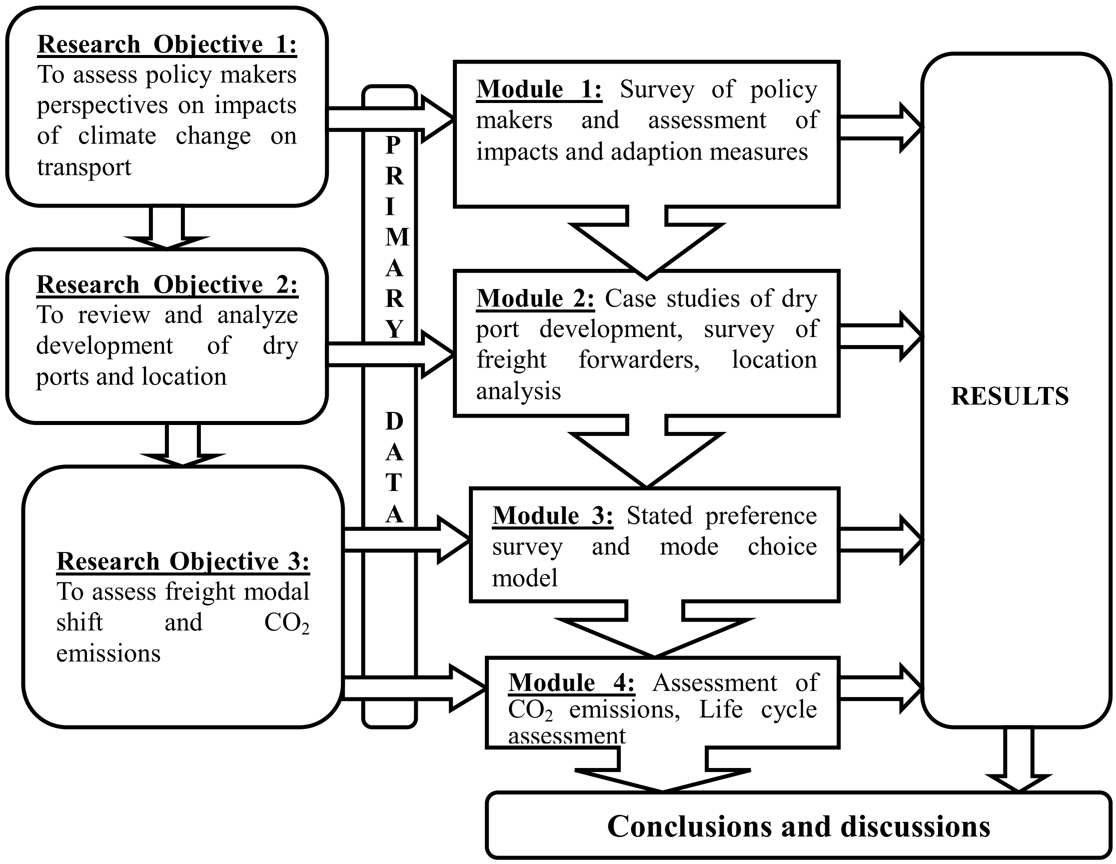


Figure 3.1 Relationship between research objectives and analysis modules

The methodological framework proposed for the study is shown in Figure 3.2. The integrated framework for analysis incorporates analytic hierarchy process, goal programming, stated preference techniques, discrete choice model, logit model and emission assessment through bottom-up approach and life cycle assessment. Due to growing concerns of freight emissions and need to reduce those, many countries are now introducing policy measures to promote intermodal transport and modal shift including through the development of dry port. However, in order to assist decision makers to make informed decisions, evaluation of such policy would be necessary. This integrated framework would help policy makers to understand the perception of stakeholders in selecting appropriate location of dry ports to promote intermodal transport, as well as to visualize what would be the potential modal shift and resulting emissions. This framework would be very useful in applied research, as it can be applied to 'real situation.' The current research proposes to evaluate the case of dry port development in Laos. The output of preceding modules serves as input to the succeeding modules in a logical sequence. This type of integrated framework incorporating various analytical modules have not been developed or used earlier in transport sector. Further, the framework aims to incorporate both adaptation and mitigation aspect of transport. Also, the research proposes to use primary data collected from government decision makers, transport officials and freight forwarders who manage and deliver freight transport services.

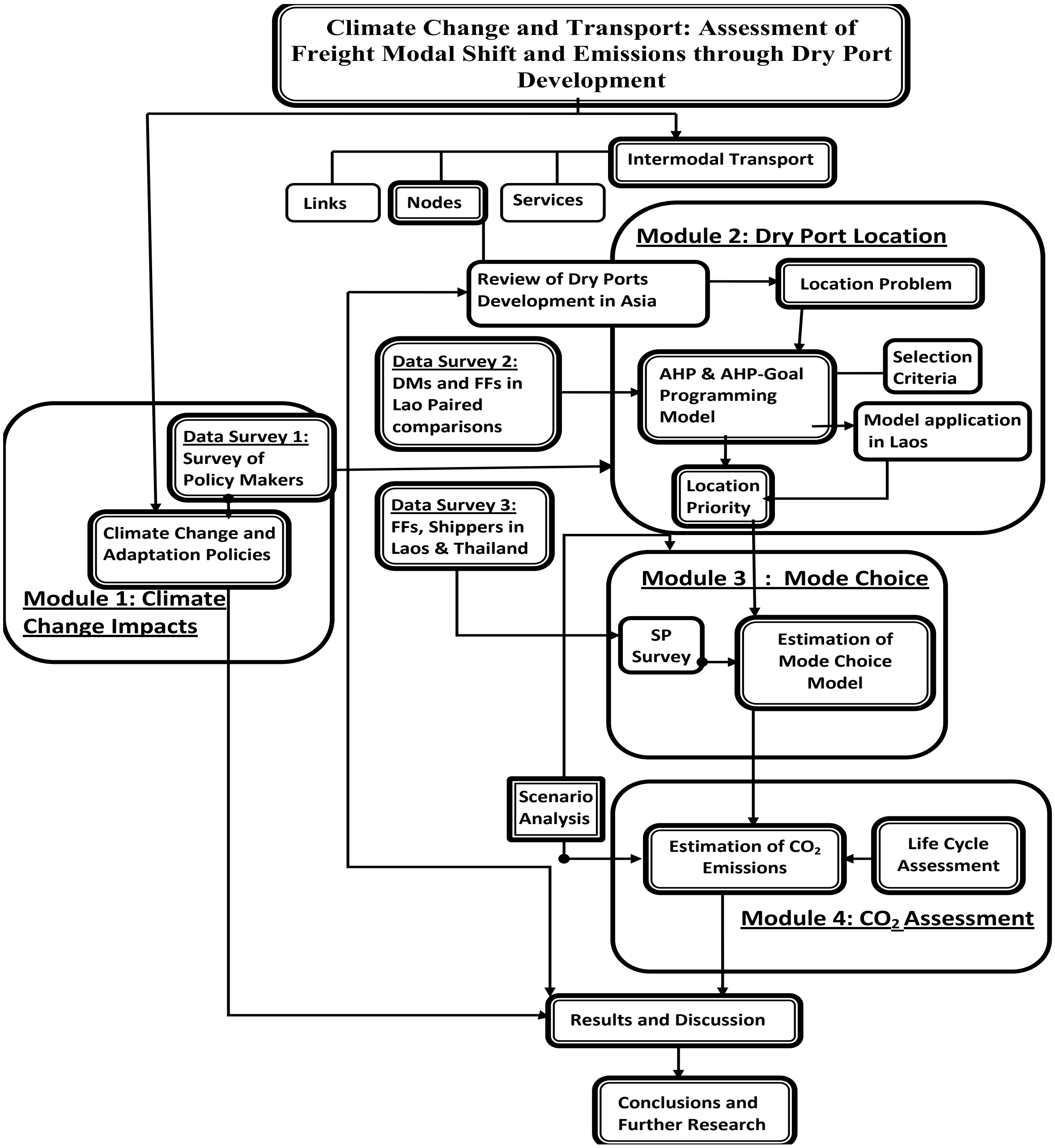


Figure 3.2 Integrated methodological framework

The following section provides details of individual analysis modules.

3.3 Module 1: Adaptation policy analysis

Initially to familiarize with the sustainable transport development agenda a survey of policy makers in Asian countries is undertaken. The survey is used to assess the understanding, awareness and the perception of policy makers on ongoing initiatives of climate change and transport, its impacts on transport infrastructure, implementation arrangements and adaptation measures. For this purpose, a questionnaire is developed and a survey of transport policy makers in Asia is conducted.

3.4 Module 2: Analysis of dry port development and location

This module incorporates review of dry port development to understand the issues and policies related to dry port taking selected case studies from Asian countries. Identifying and selecting potential location of dry ports is a challenging problem. The presence of multiple selection conflicting criteria, many stakeholders with different interest makes the location problem a multi-criteria and multi-stakeholder problem. Therefore, in analysis of dry ports location many factors and criteria that are competing and conflicting need to be considered. Economic analysis tools such as cost-benefit ratio, net present value (NPV), and internal rate of return (IRR) and environmental impact assessment (EIA) are commonly used to evaluate alternate locations and make decisions. Multi-Criteria Decision Analysis (MCDA) can help to analyze and solve the location problem. AHP one of the MCDA methodologies can consider both quantitative and qualitative criteria and derive relative weights and prioritize alternate locations based on evaluation criteria selected. To derive the local and global weights of the various criteria with respect to each location pair-wise comparison of criteria and alternatives is done based on survey of stakeholders that include government policy makers, transport service providers, chambers of commerce and industries, freight forwarders.

3.4.1 Case studies of dry port development in Asia

Countries in Asia are at different stages in the development of dry ports. In order to review the development of dry ports from environmental perspective case studies of dry ports from Asia are collected and analyzed with respect to key financial, operational, environmental, regulatory and institutional aspects of their development and operation.

3.4.2 Identification of decision criteria and sub-criteria

The first task is to develop AHP model for multicriteria decision analysis (MCDA) considering various factors and criteria that would be important in deciding the potential location of dry port. Based on review of criteria and elements considered by earlier studies (Lee 1998, Yang et al. 2009, Tuzkaya et al. 2008, Guneri et al. 2009, Wang and Wei 2009, Onut et al. 2010, Kunadhamraks and Hanaoka 2008) following criteria and sub criteria are considered for the AHP location model. AHP assumes the criteria and sub-criteria should be independent of each other.

(i) **Development and operation Costs:** Cost of land for development, construction and operation cost of dry port including transportation cost/processing cost of goods are considered. The transportation cost includes potential cost at the port, dry port charges, transshipment and clearance costs at border[1] (if any).

(ii) **Transportation time:** Total transportation time from an origin to destination (O-D) such as

[1] Ideally there should be no cost involved and process time required crossing the border- as objective of the dry ports is to enable to clear and process the cargo at dry ports. But, situation is not ideal in Asia and many part of the world still goods are checked, customs cleared and transshipment required at borders.

seaport to the dry port, as well as time required for clearance and transshipment, border crossing, and reach the final destination are considered.

(iii) **Environmental impacts:** Environmental impacts including CO_2 emissions from transport operations, as well as potential environmental impacts from construction of dry ports are considered.

(iv) **Intermodal transport connectivity:** Connectivity of dry ports to different modes of transport such as road, railway, inland waterways and sea ports are considered. Rail is considered as ideal connection from port to the dry port (Roso et al. 2009).

(v) **Regional economic development:** Proximity to market, consumers, manufacturing and processing area, prospects of economic development, freight demand, and government policies related to development of special economic zones and free trade area that can attract foreign direct investment for industries nearby dry ports location are considered.

3.4.3 AHP model development

The overall objective of the model is to rank and prioritize alternative dry port locations based on the evaluation criteria. The evaluation criteria and sub-criteria for the analysis are selected based on the review of the elements considered by earlier studies (Wang and Wei 2009, Wei et al. 2010, Kapros et al. 2005, Önüt and Soner 2008, Onut and Saglam 2008, Tuzkaya et al. 2008, Aras et al. 2004, Mohajeri and Amin 2010, Ugboma et al. 2006, Guneri et al. 2009, Kahraman et al. 2003). The final AHP model, criteria and sub criteria, is arrived after short listing relevant criteria applicable to Laos situation and consultation with experts, transport professionals and officials in Laos. The selected criteria and sub-criteria are shown in Table 3.1 and proposed model structure in Figure 3.3. In line with suggestion made in various literatures, five main criteria and 12 sub-criteria are selected to limit numbers of questions for pair-wise comparisons and to increase chance of receiving more responses during survey. A table containing detail evaluation criteria and sub-criteria used by other studies for location analysis is included in Appendix-I.

The study takes the case of dry port development in Laos. It considers four potential location alternatives namely Thanalaeng, Thakhek, Savannakhet and Phakse for dry port development. These locations represent real situation and are reflected in government five-year logistic plan (JICA 2011) and were proposed for development during a regional meeting on dry ports (ESCAP 2010c).

Table 3.1 Criteria and sub-criteria for AHP analysis of dry port location

Goal	Criteria	Sub Criteria	Alternatives
Prioritize and rank potential location of dry ports	1. Development and operation costs	1.1 Land acquisition costs 1.2 Construction costs 1.3 Transportation costs	Alt. 1. Thanalaeng Alt. 2. Savannakhet Alt. 3. Thakhek Alt. 4. Phakse
	2. Time	2.1.Total transport time from seaport	
	3. Intermodal transport connectivity	3.1 Highways 3.2 Railways 3.3 Inland waterways 3.4 Seaports	
	4. Environmental impacts	4.1 Impacts from construction 4.2 Impacts from transport operation	
	5. Regional economic development	5.1 Proximity to market, production centres and consumers 5.2 Government polices to develop special economic zone or free trade area nearby 5.3 Freight demand	

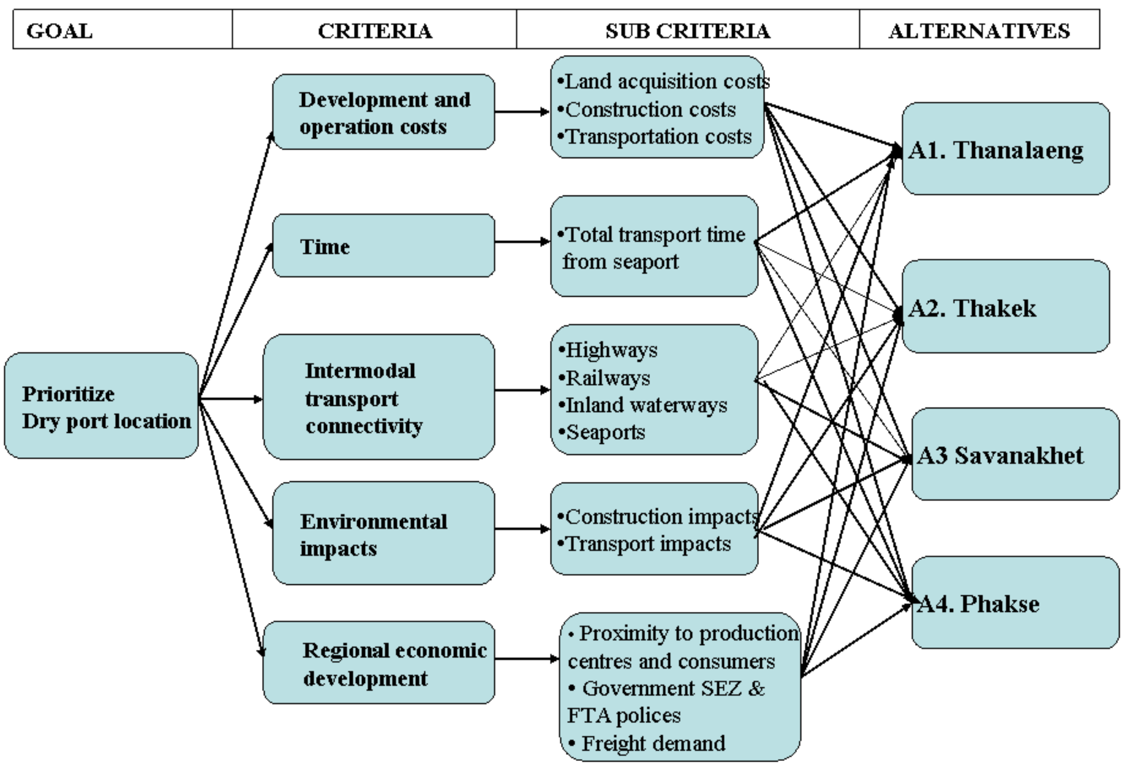


Figure 3.3 AHP model

3.4.4 Weight derivation

Relative weights of decision criteria and sub-criteria are derived by making pair wise comparison for all selected criteria at each level. The main objective of this process is to arrive at priority of the alternative locations based on the criteria and sub-criteria selected. The survey respondents are asked to provide verbal statements to assign values to paired comparison of elements. The number of pairs in each level, n (n-1)/2, are compared, where n is the numbers of elements in each level. Individual judgments are combined to arrive at the group judgment typically by taking the geometric mean method (GMM) of the individual judgment (Forman and Peniwati 1998). The aggregate weight of individual judgments is calculated by the equation (3.1).

$$a_{i,j} = (a^1{}_{i,j} * a^2{}_{i,j} * a^3{}_{i,j} * a^4{}_{i,j} \ldots\ldots\ldots\ldots\ldots\ldots\ldots * a^n{}_{i,j})^{1/n} \qquad (3.1)$$

Where,

$a_{i,j}$ - is aggregated judgment value for a pair-wise comparison,

$a^1{}_{i,j}$, $a^2{}_{i,j}$ - are individual judgments of pair-wise comparison

The qualitative judgments expressed by survey respondents are converted into numerical values. This is done by using Saaty's pair wise comparison scale as shown in Table 3.2. For quantitative criteria, the corresponding values are estimated based on the available data from survey and the value assigned from pair wise comparison and judgments are replaced.

Table 3.2 Saaty's pair wise comparison scale

Numerical values	Verbal scale	Explanation
1	Equally important	Two elements contribute equally
3	Slightly important	Experience and judgment slightly favour one element
5	Important	An element is favoured
7	Very important	An element is very dominant
9	Extremely important	An element is favoured by at least an order of magnitude
2,4,6,8	Intermediate value	Used to express between two judgments

Source: Saaty 1980

A judgmental matrix is developed based on pair-wise comparison of priorities of criteria. Pair wise comparison is done by comparing how important is "criteria 1" when compared with "criteria 2" for selecting location for development of dry ports and so on. The respondent is asked to indicate his value judgment/preference in a 1 to 9 point scale as shown in Table 3.2 while making pair wise comparison,

A judgmental matrix, A= $(a_{i,j})$ such that $a_{i,i}=1$, $a_{i,j} =1/ a_{j,i}$ for all $i, j \leq n$, is developed based on pair-wise comparison of priorities of criteria (Saaty 2003).

$$A = \begin{bmatrix} 1 & a_{12} & \ldots & a_{1n} \\ 1/a_{12} & 1 & \ldots & a_{2n} \\ \ldots & \ldots & \ldots & .. \\ 1/a_{1n} & 1/a_{2n} & \ldots & 1 \end{bmatrix} \qquad (3.2)$$

Where,
n number of alternatives,
$a_{i,j}$ represents pair-wise comparison rating between the element i and j of a criteria with respect to goal being considered

Then priorities of the criteria is estimated by calculating the principal eigenvector W of the matrix A,

$$A * W = \lambda_{\max} * W \tag{3.3}$$

Where, λ_{max} is principle eigenvalue, when vector W is normalized, it becomes vector of priorities of criteria of one level with respect to the upper level (Saaty 2003).

$$a_{i,j} = a_{i,k} * a_{k,j} \quad \forall_{i,j,k}. \tag{3.4}$$

After analyzing group judgment, the weights are derived by using by eigenvector method (linear algebra).

$$a_{i,j} = \frac{w_i}{w_j} \text{ (for i, j,= 1, 2,......n)} \tag{3.5}$$

The consistency index (CI) is calculated using equation (6).

$$CI = \frac{(\lambda_{\max} - n)}{(n-1)} \tag{3.6}$$

C. I should be below 0.2 for the survey to be accepted, C.I. zero indicates consistency in pair wise comparison, below 0.1 indicates logical consistency, if CI is more than 0.2 indicates lack of consistency and warrants repeat of survey.

Consistency is estimated by the Consistent Ratio (CR) and is inversely proportional to consistency - the lower the figure, the higher the consistency of answers. In general, if the CR is less than or equal to 0.1, the consistency is considered very high. The ratio is equal to the consistency index (CI) divided by the random index (RI). The Consistent Ratio (CR) is calculated using equation (7), generally $CR \leq 0.1$.

$$CR = \frac{CI}{RI} \tag{3.7}$$

Where,
CR is consistency ratio

CI is consistency index
RI is random index.

The measure of consistency enables analysis to review the judgments, modifying them to improve the overall consistency.
In this case, the final comparison matrix is 5X5. Table 3.3 shows comparison matrix of criteria.

Table 3.3 Comparison matrix

	TC	TT	ITC	EI	RD
TC	1	a_{21}	a_{31}	a_{41}	a_{51}
TT	$1/a_{12}$	1	a_{32}	a_{42}	a_{52}
ITC	$1/ a_{13}$	$1/ a_{23}$	1	a_{43}	a_{53}
EI	$1/ a_{14}$	$1/ a_{24}$	$1/ a_{34}$	1	a_{54}
RD	$1/ a_{15}$	$1/ a_{25}$	$1/ a_{35}$	$1/a_{45}$	1

weight
w_1
w_2
w_3
w_4
w_5

Where $a_{i,j}$ are values judgment coefficients,

TC- Total development and operation costs
TT-Total transportation time
ITC-Intermodal transport connectivity
EI-Environmental impacts
RD- Regional economic development
w_1, w_2, w_3, w_4, w_5 are corresponding derived weights of the five selected criteria

The pair-wise comparisons utilized in AHP facilitate the conveyance of the preferences of respondents, and the measure of consistency enables analysis to return to the judgments, modifying them here and there to improve the overall consistency.

The AHP model is analyzed using analysis software that also offers facilities to avoid rank reversal through use of ideal mode and distributive mode.

3.4.5 Derivation of location priorities

The overall priorities are ranked for each alternative according to the score synthesized by weights and values of criteria. Final decision is made based on ranking for each alternative.

3.4.6 Goal programming and AHP-Goal programming model

3.4.6.1 Goal programming

Weighted Goal programming (GP) is used to solve the multi-objective decision problem. It consists of decision variables and deviation variables. The AHP is used to determine the weights of various objective/criteria. Equation (3.8) shows general goal programming formulation.

$$fi(x) + d_i^- - d_i^+ = a_i \qquad \text{(for i= 1, 2..........n)} \tag{3.8}$$

Where d_i^-, d_i^+ >=0

d_i^-, d_i^+ are negative and positive deviation variables

x= decision variable

a_i is the aspiration level of the target.

3.4.6.2 Combined AHP-GP model

AHP-GP model can help decision makers to make proper decisions satisfying overall requirements of policy maker's priority and can consider budget, freight demand and other constraints. AHP output weights are used as input to GP. The goal is to minimize deviations (sufficing) from achieving multi-objectives derived based on the criteria being considered for location analysis. The combined model utilizes policy maker's perspectives/ preferences in addition to the location attributes.

In goal programming, all objectives are assigned target levels for achievements and a relative priority on achieving these levels. It treats these targets as goals to aspire for not as absolute constraints. In preemptive case, goals at higher priority must be satisfied as far as possible before lower priority goals are considered. While in non-preemptive case, different weights are assigned to each goal turning the problem to a single objective optimization (Mendoza et al. 2008). The main objective here is minimization of deviation from achieving the aspiration level of various goals. The weighted GP's objective is to find a solution that minimizes the weighted sum of goal deviations as shown in equation 3.9. The overachievement and underachievement of goals are undesirable.

It is important to develop location decision model that considers operating cost and budget and ultimate justification is based on economic terms using the coefficient and output of the AHP model makes combined AHP-GP model more robust. The model is applied to analyze four alternative locations of dry ports in Laos.

$$MinZ = \sum_{g=1}^{G}\sum_{i=1}^{m} w_{g,i}\left(d_i^- + d_i^+\right) \tag{3.9}$$

$$s.t.\sum_{j=1}^{n} a_{i,j}X_j + d_i^- - d_i^+ = b_i \tag{3.10}$$

Where,

$w_{g,i}$- weight of goal g,

$a_{i,j}$ -coefficient of decision variables (from AHP output)

X_j-decision variable, location of dry port

$d^{+/-}$ positive and negative deviational variables

b_i target value or goal of a criteria

In the case study, as there are five main criteria used to evaluate the locations, these correspond to five goals which are reformulated as constraints by adding deviational variables.

The goal of development and operation costs can be expressed as,

$$\sum_{j=1}^{n} a_{ij} X_j + d_C^- - d_C^+ = b_C \tag{3.11}$$

Total transportation time goal,

$$\sum_{j=1}^{n} a_{ij} X_j + d_{TT}^- - d_{TT}^+ = b_{TT} \tag{3.12}$$

Goal for intermodal transport connectivity,

$$\sum_{j=1}^{n} a_{ij} X_j + d_{TR}^- - d_{TR}^+ = b_{TR} \tag{3.13}$$

Goal for environmental impacts,

$$\sum_{j=1}^{n} a_{ij} X_j + d_{EI}^- - d_{EI}^+ = b_{EI} \tag{3.14}$$

Goal of regional economic development,

$$\sum_{j=1}^{n} a_{ij} X_j + d_{RD}^- - d_{RD}^+ = b_{RD} \tag{3.15}$$

Other constraints relating to capacities of proposed dry ports, freight demand, cost of development and budget available can be added.

For freight demand and capacity we have,

$$\sum_{i=1}^{4} f_i X_j = F \tag{3.16}$$

For costs and budget,

$$\sum_{i=1}^{4} C_i X_j = B \tag{3.17}$$

For AHP weights,

$$\sum_{i=1}^{4} w_i X_j = W \tag{3.18}$$

Finally as the location problem is a binary (0, 1) whether it is selected or not?

$$X_j = (0, 1) \tag{3.19}$$

We can also introduced a constraint in the GP model to ensure at least one dry port site is selected,

$X_1+X_2+X_3+X_4>=1$ (3.20)

The deviational variables are non-negative,

$d_i^-, d_i^+ >=0$ (3.21)

Where,
X_j- is location of dry port
b_C, b_{TT}, b_{TR}, b_{EI}, b_{RD}- right hand side coefficients corresponding to costs, transport time, transport connectivity, environmental Impacts and regional development
C_i- Cost of dry port i,
B- Total budget available
f_i- Freight demand of dry port i,
F- Total freight demand
L- Distance from port to dry port
E- Target value for CO_2 emission
w_i-corresponding AHP weights.

There are various approaches used to determine target value of different objective criteria (right hand side of the constraint in equation). Firouzabadi et al. (2008) suggested using largest partial weights of intangible criteria. While, Badri et al. (2001) recommended to add the best two or three coefficients of criteria. LINDO software can handle both preemptive and non-preemptive optimization problem and it is used to solve the AHP-GP model.

The four alternatives dry port locations considered are: (i) Thanalaeng; (ii) Thakhek; (iii) Savannakhet; and (iv) Phakse (see Figure 1.1). These are the real locations proposed by Laos for development. The mode shift model considers freight transport between seaport in Thailand to dry ports in Laos. These four locations provide four possible routes for mode choice analysis and emission assessment which are: Laem Chabang Port-Thanalaeng; Laem Chabang Port-Thakhek; Laem Chabang Port-Savannakhet; and Laem Chabang Port-Phakse. For mode choice analysis, the O-D pair with highest ranking (priority) location of dry ports in Laos determined by AHP and AHP-GP model based on survey feedback of government decision makers and freight forwarders is to be used for stated preference (SP) survey and development of a mode choice model and assessment of CO_2.

3.5 Module 3: Mode choice model

3.5.1 Model structure

The development of mode choice model involves selection of modes, mode attributes, utility function and model estimation that includes estimation of parameters and mode shift. The problem has two mode options truck and train.

3.5.2 Attributes

The attributes to be considered for mode choice are total transportation time, transportation cost (including dry port charge), and reliability (delay) of service for both truck and freight train.

3.5.3 Utility functions

The generalized utility function is shown in equation (3.22). The chances of selecting a mode largely depend on the observed component of the utility.

$$U_i = V_i + \varepsilon_i \tag{3.22}$$

Where, U- Utility function
V- Systematic utility
ε -random component of utility
i is transport mode.

As transportation time, transportation cost and reliability of a mode are selected, the mode specific utility functions for truck and rail modes can be expressed as linear function as perceived by user n is shown in equation (3.3) and (3.4).

$$U_{truck} = V_{time} + V_{\cos t} + V_{rel} + \varepsilon_{truck} \tag{3.23}$$

$$U_{rail} = V_{time} + V_{\cos t} + V_{rel} + \varepsilon_{rail} \tag{3.24}$$

Thus the probability of choosing 'rail' instead of 'road' is the probability of that U_{rail} is greater than U_{road}, and is given by equation (3.25).

$$\mathrm{P}_{rail} = P(U_{rail} > U_{truck}) \tag{3.25}$$

The probability of selecting the rail mode is given by equation (3.26).

$$P(rail) = \frac{\exp(V_{rail})}{\exp(V_{rail}) + \exp(V_{truck})} \tag{3.26}$$

3.5.4 Model estimation

Stated preference (SP) survey is conducted to seek response from freight forwarders and transport service providers in Laos and Thailand. The SP presents hypothetical situation if dry ports are developed, railway is connected, and service is available, frequency of freight train, transportation costs including charges for dry ports use. The survey also includes other questions relating to policies, services that would be important for considering a mode shift. Providing map based route information to users can induce route choice, similarly, provision of information on freight route, transfer facilities, time, and costs could influence freight mode choice. Clean Development Mechanism (CDM) recognizes "modal shift" as one of the approved methodology (UNFCCC 2010).

Model estimation is done by using LIMDEP econometric software to estimate model parameters including log likelihood ratio. After determining the attributes values, utility function of each mode, the mode share is estimated using equation (3.26).

3.6 Module 4: Assessment of CO_2 emissions

The assessment of CO_2 emissions involves estimation of CO_2 emissions from operation of freight transport from seaport to dry port taking account of the potential modal shift from. It also estimates life cycle CO_2 emissions from dry port construction and transport infrastructure.

3.6.1 Emissions from operation

The CO_2 emissions from operation of freight transport from the seaport to the dry port are assessed utilizing bottom-up approach. The mode shares estimated by the mode shift model are utilized to calculate CO_2 emissions from transport operations. The emission factors are derived for Thailand (Chamroon 2011) as these factors are similar to Laos since the type of vehicles and train to be used are similar.

The emissions are estimated using the following equation (3.27):

$$E_{i,j} = \sum EFV_{i,j} * VTKm_{i,j} + \sum EFT_{i,j} * TTKm_{i,j} \quad (3.27)$$

Where,

E- Emissions
EFV= Emission factor for the vehicle for the fuel type,
EFT-emission factor for the train for fuel type
VTKm- total freight transported by vehicle in ton-km
TTKm- total freight transported by train in ton-km.

3.6.2 Life cycle assessment of construction

The life cycle emission assessment for the selected dry port location is done utilizing the result of location analysis. Depending on the site selected, it involves estimating the quantity of dry port construction and road or railway connection to the seaport. If Thanalaeng is selected it will involve construction of dry port, road and railway sidings inside the dry port. However, for Thakhek, Savannakhet and Phakse, in addition to the dry ports the railway connectivity to the seaport has to be constructed as well.

The quantities of main construction items such as earthworks, cement concrete for roads and container yard, building with steel and concrete structure and railway construction with the dry port are first estimated. The life cycle emission factor that incorporates from raw material acquisition, construction process, use of equipments and disposal (from cradle to grave) are of used. The product of construction quantity and life cycle emission factor per unit give the total life cycle emissions. The life cycle emission is estimated using the following equation (3.28).

$$LC\text{-}CO_2 = \sum Q_i * LCEF_i \qquad (3.28)$$

Where,
$LC\text{-}CO_2$ is life cycle CO_2 emissions
Q_i is quantity of construction items i,
$LCEF_i$ is life cycle emissions factors per unit of construction item i
i is construction items such as earthworks, cement concrete, types of buildings, railway line.

The life cycle assessment (LCA) evaluates construction related CO_2 emission due to infrastructure development. Construction quantities estimated by the feasibility study are used (JICA, 2011). The life cycle emission factors for the construction are difficult to find in Asian context. Instead, the life cycle emission factor from the Ecoinvent database is used (Ecoinvent, 2007).

Assessment of emissions from potential modal shift and LCA of transport infrastructure development will used to determine net emissions and estimate time required to offset the emission from construction of the dry port and related infrastructure.

3.7 Scenario and elasticity analysis

Different likely scenarios are considered to assess the effect on modal share and resulting CO_2 emissions. Elasticity analysis would be conducted to see the variation on modal shift and emissions due to variation in transport cost and time of freight transport. Some of the likely scenarios that could be evaluated are:

(i) Variation in transportation cost of truck and train;
(ii) Variation in transportation time of truck and train;
(iii) Variation in cost and time of truck and train;
(iv) Evaluate resulting change in the mode shift of truck and train; and
(v) Evaluate resulting CO_2 emissions.

3.8 Model limitations

Only international freight transport to and from Thailand is considered both bilateral and international export/import trade to third countries. It is assumed that the transportation of distribution leg in the Laos from dry ports to consumers and production centres and to industry is done by road transport and would be the same now and after the development of the dry ports. Therefore, this distribution leg is not considered in the model. Growth of international freight is considered based on projected trade growth based on GDP growth in Laos.

Majority of the international freight travel occur in Thailand. It does not discuss how this is accounted for Laos and Thailand. Emissions being global issue, overall emissions reduction potential along the corridor are assessed.

3.9 Data collection and surveys

Four sets of primary data are collected for the research from policy makers, private sector freight forwarders and reprehensive of commerce and industry. The first stage was a survey of policy makers in Asia on climate change impacts on transport and adaptation policies. Secondly, a survey on the judgment and evaluation of government decision makers, private sector freight forwarders and transport operators for assessment of alternative dry port locations in Laos was conducted. Thirdly, a stated preference survey of freight forwarders and multimodal transport operators in Laos and Thailand was conducted to develop freight mode choice model between truck and train. Fourthly, visits to dry ports in Asia were undertaken to collect data for case studies of development of dry ports

The schedule, method, targeted respondents and areas of primary data collection are depicted in the Table 3.4.

Table 3.4 Primary data collection schedule, method and area

S. No.	Data description	Schedule	Method	Survey Area	Targeted respondents
1.	Perception of climate change impacts on transport and policies	June-July 2009	Email survey	Asian Countries	Transport policy makers
2.	Pair-wise comparison of evaluation criteria/sub-criteria and dry ports locations	July-August 2011	Interview survey, email survey and visit to potential locations	Laos	Policy makers, freight forwarders and representative of commerce and industries
3.	Stated preference survey of freight mode choice between truck and train	September-November 2011	Interview survey and follow-up by telephone and emails	Thailand and Laos	Freight forwarders and transport operators
4	Data collection for case studied of dry ports	June 2010-September 2011	Visits to the dry ports, interview and discussion with officials	China, South Korea, Uzbekistan, Bangladesh and Nepal	Dry port developers and operators

In addition to the above mentioned structured primary data collection various interviews, consultation and discussion were undertaken with the freight forwarder and government policy makers in Laos and Thailand to understand the insight of freight logistics, international freight transport and the prospects for introduction of freight rail service between Thailand and Laos. Further, secondary data were also collected and used for the study. These includes collection of secondary data relating to costs, time, distance of the route, freight volume, emission factors, and government infrastructure development policies.

Further details on data collection and survey including the approach, questionnaires design, and selection of respondents for data collection survey and face-to-face interviews are included in respective analysis Chapter 4, 5, 6 and 7.

3.10 Chapter summary

This chapter provided details of framework and methodology used for the research involving four modules. The modules 1, 2 and 3 correspond to the research objectives 1, 2 and 3 respectively and module 4 corresponds to objective 3. Details of analytic hierarchy process, goal programming and logit model is provided. This integrated framework would be very useful tools for transport professional, policy and decision makers in order to make rational decisions regarding the development of dry ports as well as reduction on emissions from freight transport. It also introduced the methodology of primary data collection for the research.

The integrated methodology developed is applied in the Asian context. In developing adaptation strategies the views of policy makers from Asia are considered. For location analysis, the case of dry ports development in Laos is evaluated; and international freight movement between Thailand-Laos is considered for modal shift with feedback of freight forwarders and emission assessment. The next chapter discusses the application of module 1 to assess the impacts of climate change on transport.

CHAPTER 4

IMPACTS OF CLIMATE CHANGE ON TRANSPORT[2]

4.1 Introduction

The recent frequent occurrence of extreme weather events in Asia provides some evidence of increased intensity and frequency of climate events. Asia is expected to experience rises in temperature, longer summer heat spells, more intense and more frequent precipitation, increased extreme rainfall, a higher number of extreme tropical cyclones, and rises in sea levels. Transport infrastructure and service are affected by these climate events. Increases in temperature and precipitation, rises in sea levels, and storm surges significantly affect planning, design, construction and maintenance, and operation of transport system. This chapter presents the regional climate predictions for Asia and the findings of the survey of policy makers on impact of climate change and transport. It then assesses the impacts of climate change on transport and list vulnerable transport infrastructure. Finally, adaptation strategies and measures to safeguard transport infrastructure including dry port and possible ways of financing adaptation are outlined.

4.2 Regional climate predictions for Asia

The IPCC Fourth Assessment Report (Christensen et al. 2007) predicts warming is likely[3] to be well above the global mean in Central Asia (3.7^{0}C), on the Tibetan Plateau (3.8^{0}C), and in Northern Asia (4.3^{0}C); above the global mean in Eastern Asia (3.3^{0}C) and South Asia (3.3^{0}C); and similar to the global mean in South-East Asia (2.5^{0}C). Precipitation in boreal winter regions is highly likely to increase in Northern Asia and on the Tibetan Plateau, and also likely to increase in Eastern Asia and the southern parts of South-East Asia. Precipitation in summer is likely to increase in Northern Asia, East Asia, South Asia, and most of South-East Asia, but is likely to decrease in Central Asia. It is very likely that heat waves and hot spells in summer will be of longer duration, and these events will be more intense and more frequent in East Asia. Fewer very cold days are highly likely in East Asia and South Asia. There is very likely to be an increase in the frequency of intense precipitation events in parts of South Asia and in East Asia. Extreme rainfall and winds associated with tropical cyclones are likely to increase in East Asia, South-East Asia, and South Asia.

The rise in sea level is likely to be in the range of 18–59 cm depending on the scenarios predicted. Rises in sea levels are likely to be average around the Indian Ocean and the northern and southern Pacific Ocean. The Indian Ocean and the North and South Pacific Islands are very likely to warm during the century, but the warming is likely to be somewhat less than the global annual mean. Annual rainfall is likely to increase in the northern Indian Ocean and in the equatorial Pacific. Significant increase in annual runoff of major Siberian Rivers, expansion of

[2] Part of this chapter was published as Regmi, M. B. and Hanaoka, S. (2011) A survey on impacts of climate change on road transport infrastructure and adaptation strategies in Asia, Journal of Environmental Economics and Policy Studies, (2011) 13:21-41. The paper was the highest downloaded paper during June to December 2011. The paper is available from: (http://www.springerlink.com/content/g783546t53271847/)

[3] The IPCC report uses standard terminology for the likelihood of occurrence: virtually certain>99% probability; very likely >90% probability; likely >66% probability; more likely than not >50% probability; about as likely as not 33–66% probability; unlikely<33% probability; very unlikely <10% probability; exceptionally unlikely<1% probability.

deserts, more frequent and severe water crises, and increased rainfall intensity during the summer monsoon and increase flood risk in the flood-prone areas in Asia are expected.

4.3 Survey of impacts of climate change on transport

A survey of climate change impacts on transport and adaptation in Asia was conducted during June-July 2009 to assess: (i) the level of awareness of policy makers and general public; (ii) the level of response and coordination to climate events related emergencies; (iii) adequacy of current design standards and practices; and (iv) adequacy of existing policies, institutional arrangements and coordination. The finding of the survey is also used to assess the potential impacts, identifying vulnerable transport infrastructure and planning adaptation strategies and measures.

4.3.1 Questionnaire development

A questionnaire consisting of 28 questions divided into four sections was developed. The four sections included in the questionnaire are: (A) awareness of climate change and adaption measures in transport sector; (B) information on emergency preparedness; (C) design standards and practices; and (D) policy, guidelines, institution, coordination for implementation. The questionnaire also included a section (E) on information about the respondents. A pre-test of the questionnaire was done by sending it to the master and doctorate students undertaking research in the area of transport for feedback and comments. The questionnaire was finalized incorporating the comments and suggestions received during the pre-test. The survey questionnaire is attached as Appendix-II.

4.3.2 Selection of respondents

Transport professionals working within transport ministries, departments and agencies from 30 Asian countries were selected for the survey based on the existing contact. Even though the Pacific Island countries are potentially affected by the climate events such as the rise in sea level they were not included in the survey simply because of lack of contacts.

The questionnaire was sent to 81 transport professionals by emails in 30 Asian countries. At least two officials representing each country were requested to provide their opinion. Total 24 responses from 21 countries (total 30% response rate covering 70% of countries) representing all four subregions[4] within Asia were received namely from: Azerbaijan; Bhutan; Cambodia; China; India; Indonesia; Iran; Japan; Kazakhstan; Kyrgyzstan; Malaysia; Mongolia; Myanmar; Nepal; Pakistan, South Korea; Singapore; Thailand; Turkey; Uzbekistan; and Vietnam.

4.3.3 Respondents details

Figure 4.1 shows the distribution of respondents by age, gender and geographical subregion. It shows the majority of respondents were male (79%) and only 21% of the respondents were female representing all four subregions of Asia. In terms of age group, the age group 41-50 years

[4] Four subregions of Asia classified by the United Nations are: Central and South-West Asia; North and North-East Asia; South Asia; and South-East Asia.

(42%) has highest number of respondents followed by 52-60 years group with 25%.

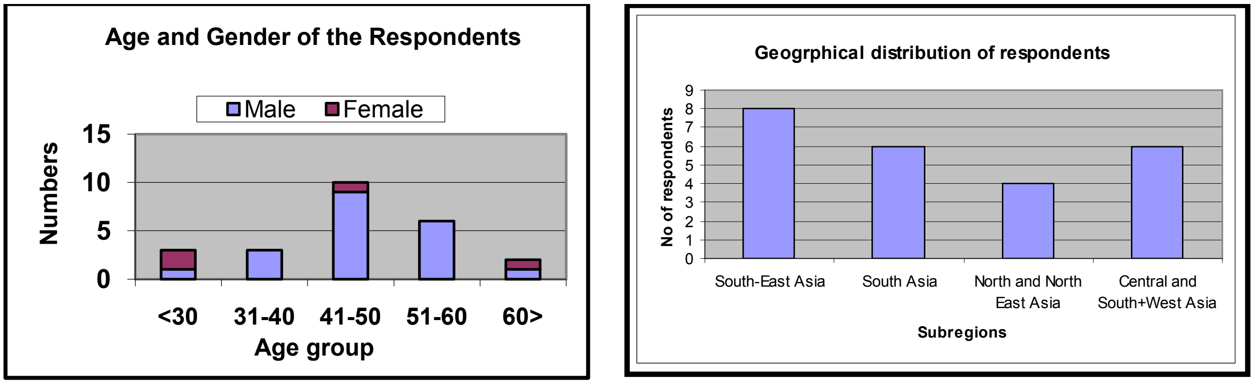


Figure 4.1 Age, gender and geographical distribution of respondents

Figure 4.2 shows the education level and experiences of the respondents. It shows most of the respondents were with masters degree (62.5%) followed by bachelors degree (25%) and only three respondents were with doctorate degree (12.5%). In terms of experience, majority of the respondents were with more than 15 years of experiences (58%) followed with experience range 11-15 years (17%). The respondents having more than 10 years of experience were 75%.

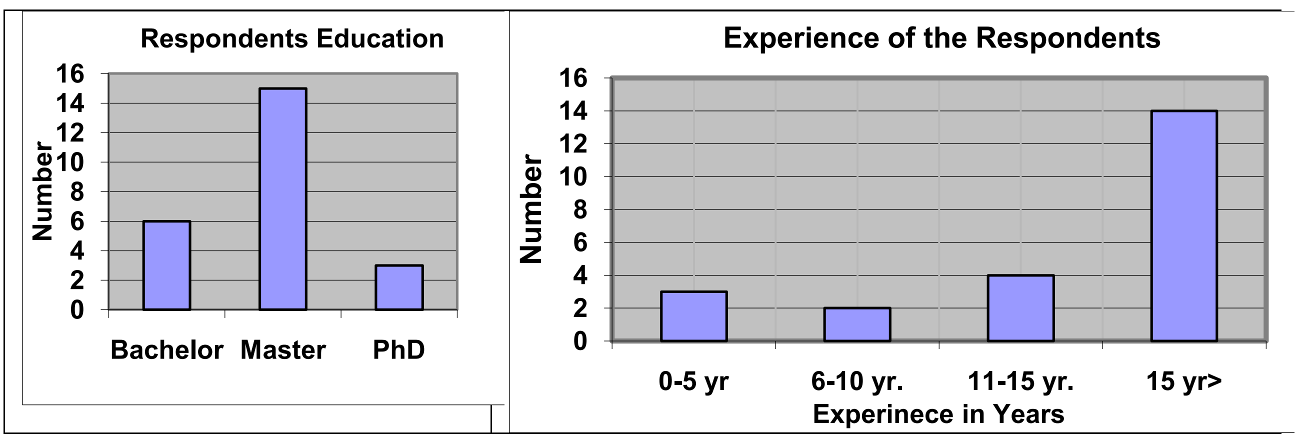


Figure 4.2 Education level and experiences of the respondents

The age group, education and level of experience of most of the respondents can reflect the high level of maturity and can be interpreted to reliability of the survey and response received.

4.3.4 Limitation of the survey

The survey has limitation in terms of total number responses received. Therefore, the findings have some limitations. However, as most of the respondents were senior transport officials with more than 10 years experience and some of the respondents mentioned that they had consulted officials working in the area of environment and climate change while completing the questionnaire, the responses can be considered reasonably acceptable to reflect current situation in Asia without much bias. However, caution should be taken in utilizing and interpreting the results.

All the survey responses were tabulated and summarized corresponding to each questions in four main sections after adjusting some outliers responses. However, we can see both similarities as well as differences on the responses received which is solely by coincidence. The analysis and findings of the survey would be helpful in assessing impacts, planning interventions and adaptation strategies to the climate change impacts at regional, subregional and country level.

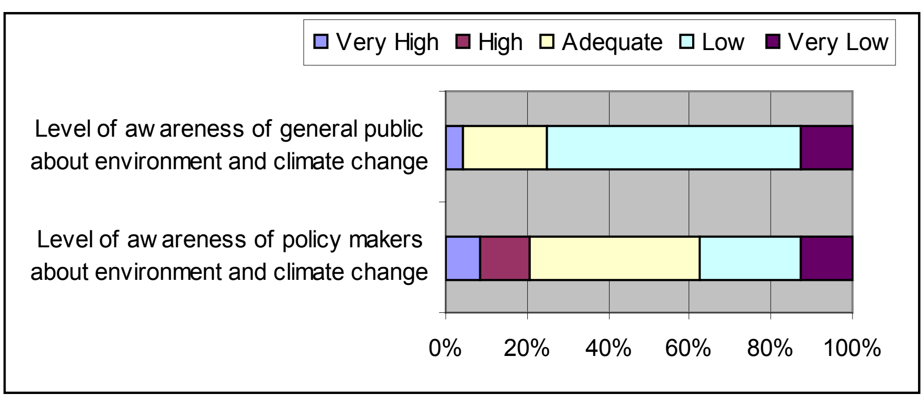
4.3.5 Findings of the survey

The following section outlines the findings of the survey of policy makers on climate change impacts on transport and adaptation. It assesses the level of awareness, institutional arrangements, and coordination, existence of rules and design guidelines, and current practices of incorporating climate change impacts on transport projects in Asia. It also includes additional feedback provide by the respondents on transport and climate change

4.3.5.1 Awareness of climate change and adaptation

Figure 5.3 shows the different level of perception of awareness of policy makers (government officials) and general public about the climate change, transport and environmental agenda. The respondents were asked to rate the level of awareness on a five point Likert Scale (5, very high; 4, high; 3, adequate; 2, low; 1, very low). As seen in Figure 4.3, the level of awareness of the general public rated as low or very low is 75% while the level of awareness of policymakers rated as low or very low is 38%. This difference may be a result of ongoing climate change advocacy programs reaching government officials but not the general public. This clearly shows that there is scope to improve the awareness of the general public and to further enhance the awareness levels of policymakers.

Indonesia and Japan mentioned that the level of awareness of policy makers and transport officials was very high. Contrary to this Kazakhstan and Nepal indicated that the awareness level was very low. Similarly, Bhutan and Japan indicated the very high level of awareness of general public while Nepal and Thailand indicated as very low.



% low
75
38

Figure 4.3 Awareness levels of policy makers and general public

Despite numerous global efforts in tackling the issues of climate change, the levels of understanding and coordination have yet to be matched by those required The situations are similar in the United States and the United Kingdom where there is still some scope to improve awareness in the transportation sector (Woollier 2003, DOT 2007; NRCNA 2008).

The respondents were also asked to rate 14 statements related to climate change and transport by using a five-point Likert scale (1, strongly disagree; 2, disagree; 3 neutral; 4, agree; 5, strongly agree). Figure 4.4 shows the response received and confirm the broad beliefs on climate change and the potential impacts on transport infrastructure. Some of the rankings highlight the importance of particular aspects of impacts and adaptation. Most of the respondents (79%) strongly disagreed or disagreed with the statement "Our region will not be much affected by climate change," indicating that climate change is a cause of concern in Asia.

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

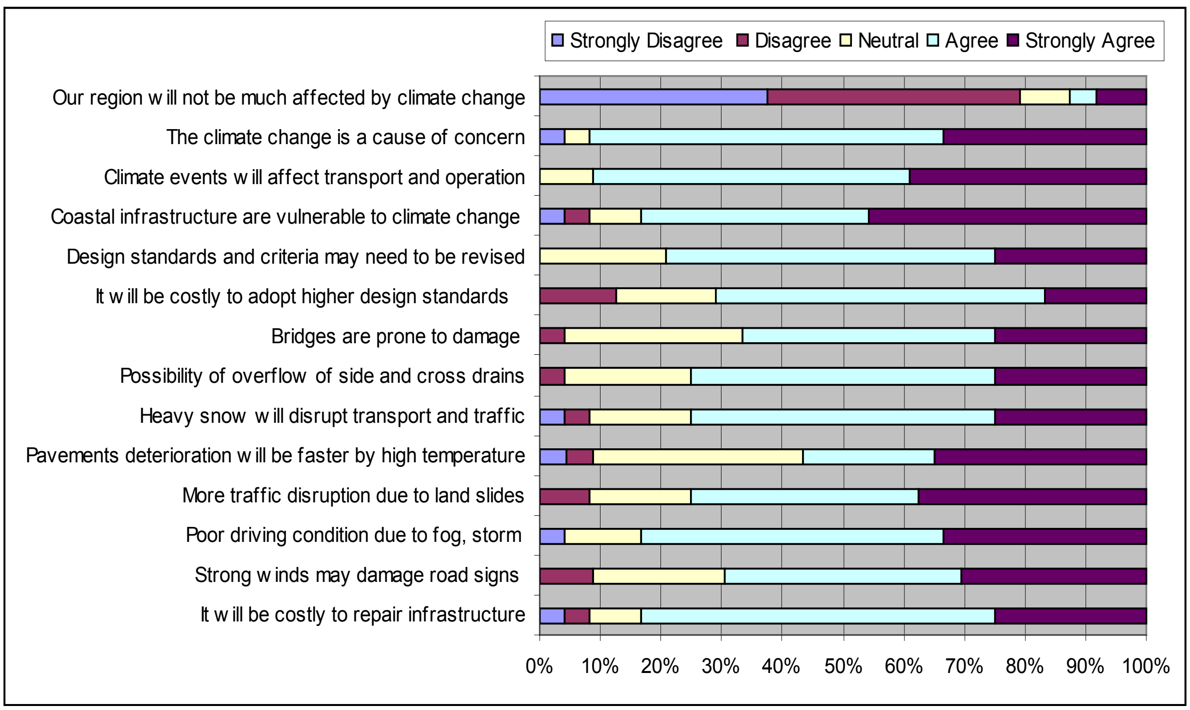
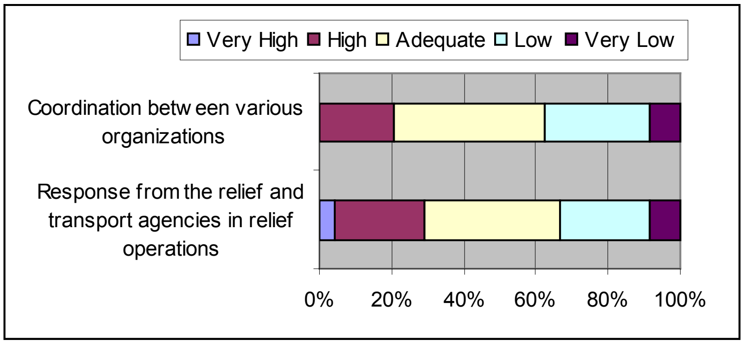


Figure 4.4 Response to transport and climate change related statements

4.3.5.2 Emergency preparedness

Transport plays a vital role in mobilizing immediate help and relief to the area affected by the extreme climate events. All respondents indicated that extreme climate events had occurred within the past three years. Figure 4.5 shows the level of response and relief coordination of government agencies during emergencies. The respondents indicated that the coordination and response to emergencies have been adequate. However, it also shows that there is some scope of improvement as indicated by the combined low and very low score of 38% for coordination and 33% for relief operation. All respondents except Kazakhstan and South Korea indicated that there is some scope of improvement in the way the help and relief operation are managed.



% low

38

33

Figure 4.5 Level of response and coordination during emergencies

Respondents from Azerbaijan, China, Indonesia, Iran, Japan, Kyrgyzstan, Mongolia, Myanmar, Singapore, Turkey, South Korea and Uzbekistan indicated that some policy initiatives and improvement in dealing with emergency preparedness had occurred after recent extreme climate events. Furthermore, the survey clearly showed the scope to improve coordination among various relief and transport agencies dealing with evacuation planning and emergency relief operations. Transport infrastructure including roads along important routes would require more frequent inspection and monitoring of condition to ensure immediate access to plan and provide assistance.

4.3.5.3 Design standards and practices

Figure 4.6 shows the cumulative responses to the fourteen design standards and practice related statements, and clearly demonstrate that rain and flood related damages is a major cause of concerns in Asia. The low ranking of the statements related to coastal roads could be because the Pacific island countries were not included in the survey. Similarly, the low rating of snow impact-related statements could be due to less response received from countries experiencing severe cold climates.

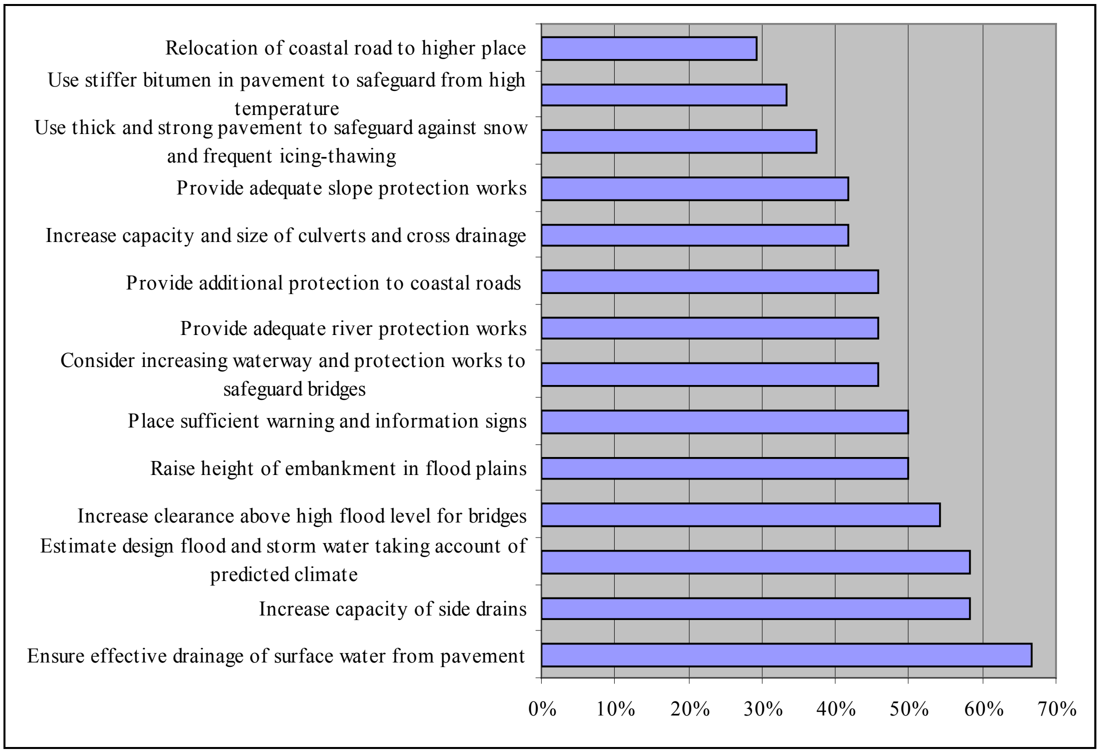


Figure 4.6 Response to design standards and practice related statements

Figure 4.7 shows the response to design and policy related questions, and clearly indicates the need to consider climate change impacts in planning and designing transport infrastructure, the need to review the existing design standards, and the need for clear policy guidelines to consider climate impacts. The survey also indicated the need to review design standards in relation to forecasting design discharge, freeboard, height of embankments, and additional protection measures necessary for critical components of transport infrastructure such as drainages, bridges, culverts, pavements, coastal roads, and slopes. However, Cambodia and China indicated there is no need to review or revise the design standards to consider the climate change impacts. Further, Cambodia, India and South Korea indicated that it may not be appropriate to revise design flood estimation methods contrary to other response. Adopting new design standards is relatively easy at the planning stage. Many respondents have suggested streamlining construction guidelines and practices taking account of climate events. In addition, there will be subregional variations in scale and type of impact depending on location and topography. Therefore, different and appropriate adaptation policies, strategies, and measures need to be taken. Depending on the severity of climate impacts, the frequency of maintenance activities may have to be increased. Regular clearing the drains, vegetation, more frequent inspection of road signs and steel bridges for corrosion will be required. Installment of additional warning information boards and signs, strengthening of coastal protection would help operation.

As indicated by the survey, in many cases it may be beneficial to review the design life of various components of the transport infrastructure. There are ample studies and examples of adaptation measures applied mostly in developed countries. While applying these examples in an Asian context technical and economic viability as well as life-cycle costing should be evaluated for the proposed design and adaptation measures depending on the capability and affordability of the country. Differing from the general view Cambodia, China, Japan, Nepal and Uzbekistan viewed that adopting higher standards may not be economical in long run because of high initial cost.

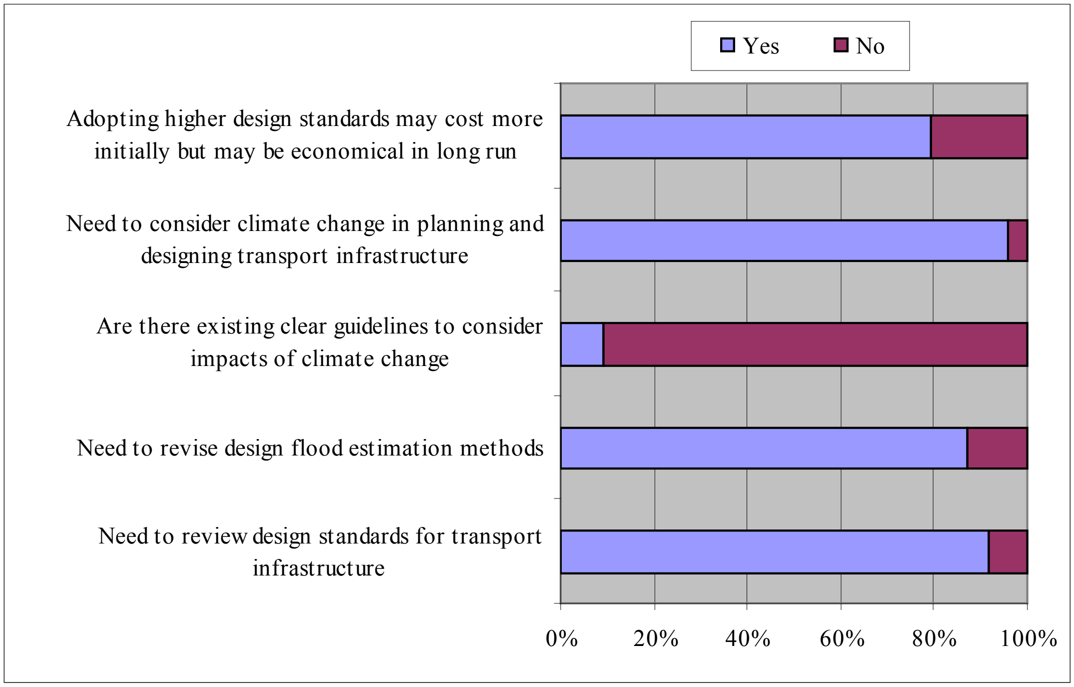


Figure 4.7 Response to design and practice questions

4.3.5.4 Policies, institutions and coordination

Figure 4.8 shows the response to questions related to policy, institutions and coordinated. 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, South Korea, Thailand, and Turkey indicated that there are existing laws, rules and guidelines. However, most of the laws, policies, and guidelines listed were related to the environment, global warming, and air pollution and very few were related to transport and climate change. Most of the respondent favoured extension of the existing transport and road sector environmental impact assessment guidelines to include the climate change and adaptation issues.

The environmental impact assessment (EIA) process is well recognized and followed in Asia. The EIA process includes assessment of potential environmental impacts, planning, implementing and monitoring mitigation measures during construction and operation. In the beginning the environmental guidelines (United Nations 2002, ADB 2003) could be appropriately extended and revised to take account of risk and uncertainty of climate change. The guidelines would be useful in incorporating the effect of predicted climate events into project design and enhancing the understanding of climate change (Lemmen and Warren 2004). It would be easier to expand these environmental guidelines rather than developing new guidelines, which may take long time. There are some initiatives by donors to introduce guidelines on climate change and adaptation but they are general and not specific to the transport and road transport sector. Therefore, as indicate by the survey, there is a pressing need to develop guidelines for climate change impact assessment in the transport sector. Respondents indicated that there were ongoing adaptation projects in the transport sector in China, Indonesia, Mongolia, Myanmar, South Korea and Turkey.

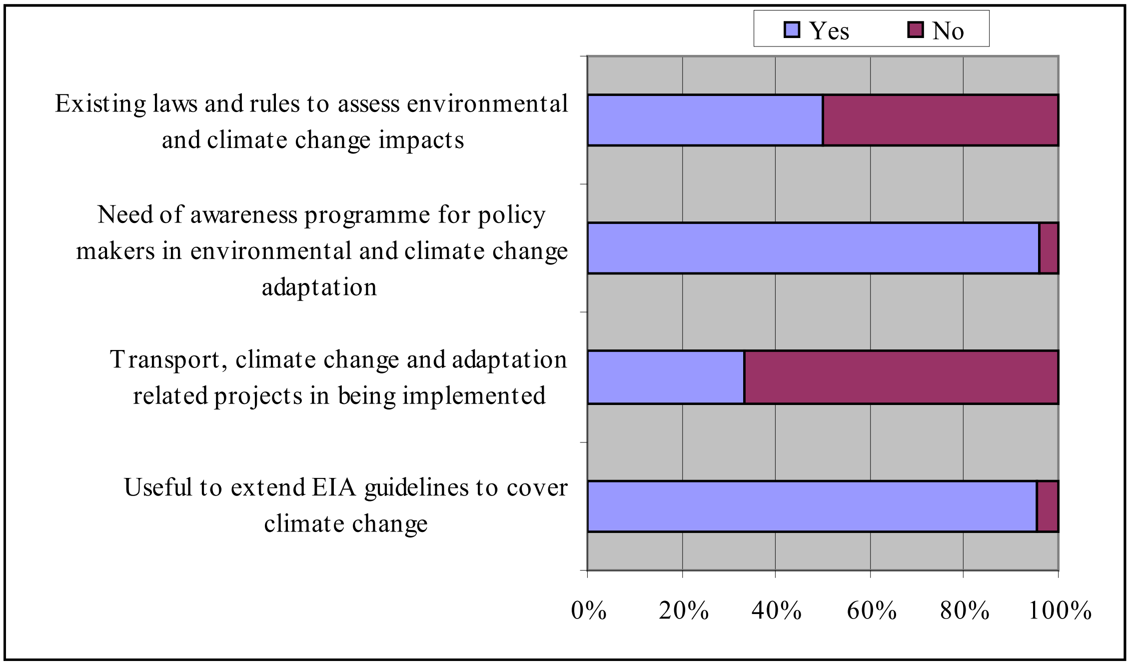
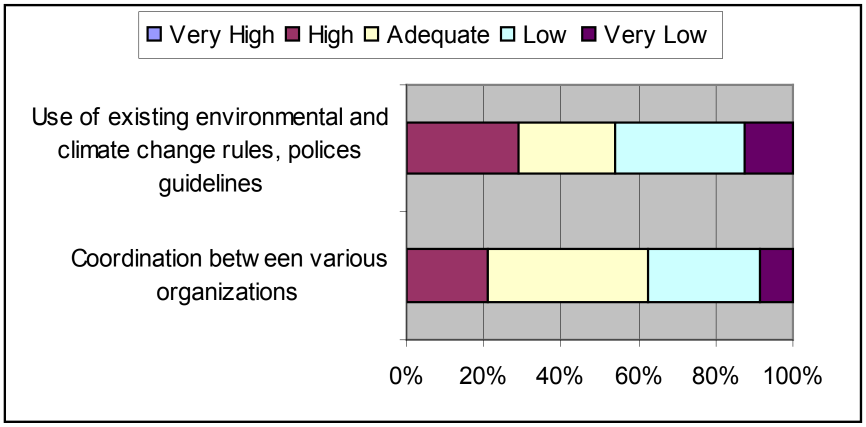


Figure 4.8 Response to policy and institutions related questions

Most of the respondents (83%) indicated the existence of a central level coordination body in their country responsible for environment and climate change and 61% of the respondents indicated the existence of a coordinating unit or division within the line ministries and road/ highway/railway department. Figure 4.9 shows the response to questions related to coordination and level of implementation of existing environmental policies, rules and guidelines. The results clearly indicate the need for greater collaboration and effective implementation of environmental and climate change policies and guidelines. Nepal and Thailand indicated the application and implementation of existing environmental, climate change and adaptation guidelines as very poor.



% low

46

38

Figure 4.9 Coordination and policy implementation

The survey also revealed the need to establish units, divisions or branches to be responsible for dealing with climate change issues within line ministries and road/highway/railway agencies. In order to improve coordination among various agencies, these organizational units should be strengthened so that they could effectively advocate, initiate and implement climate change policies. These units need to be adequately staffed with trained professionals in assessment of climate change impacts and implementation of adaptation measures. UNFCCC has recognized the capacity building needs for developing countries and countries with economies in transition. The impacts of climate change could be widespread as well as localized so that coordination at central, regional and local level is essential in planning and implementation of adaptation measures. Structural limitations of organizational system and functions of bureaucracy are usually found in Asia. Because climate change is multidisciplinary issues, coordination among various institutes and capacity building of staff are essential. The Climate Cell Centre in Bangladesh and the Office of Climate Change in the United Kingdom are examples of institutions established for coordination of climate change policy at the national level (DOT 2007).

4.3.5.5 Additional feedback from the respondents

The survey also included questions seeking respondent's suggestions for making transport infrastructure safe to withstand the impacts of climate change and what should be done to safeguard transport infrastructure from impacts of climate change. Some of the notable suggestions included the need to:

(a) Integrate impacts of climate change in the present planning and design;
(b) Organize workshops, trainings and seminars to increase understandings and awareness of politicians, policy makers and general public;
(c) Update and revise construction and drainage standards, guidelines and code of practices;
(d) Strengthen EIA process to take account of climate change;
(e) Utilize available technology to predict weather more accurately and share/provide timely information to the designer and planners;

(f) Ensure adequate periodic supervision of transport infrastructure;
(g) Avoid cost cutting measures however evaluate technical and economic viability as well as life-cycle costing of the proposed design;
(h) Undertake a detailed survey of impacts of climate change on transport;
(i) Incorporate climate proofing and risk assessment while developing national plans;
(j) Increase investment for development and maintenance of transport infrastructure;
(k) Plan adaptation measures on the capability and affordability of the country; and
(l) Ensure good cooperation among all stakeholders and people in the society.

The respondents also offered suggestions to utilize alternate fuels and energy efficient engines to reduce emissions, and encourage modal shift to reduce pollution. They also mentioned that it is difficult to plan solutions during emergencies therefore provision of information on climate events and potential effects to the designer, implementing agencies, managers and executing agencies in some rational ways becomes very critical. Further, good cooperation among all stakeholders is essential in planning and implementation of adaptation measures.

4.3.5.6 Summary of the findings

There is much focus on mitigation not many initiatives are in areas of adaptation. It was clear that lack of awareness at all levels of the government from policy making to project implementation and general public. Also, the need for strategic direction and guidelines, as 50% responded mentioned those, even use and implementation of existing rules and guidelines was not evident. Therefore, implementation of adaption measures can be considered more of policy and institutional issues. Based on the findings of the survey, the following points are considered important to safeguard transport infrastructure in Asia:

(i) Advocate and create a greater level of awareness in the general public
(ii) Further enhance awareness among policymakers and managers
(iii) Initiate polices and extend EIA guidelines to include climate change impacts into planning processes
(iv) Review design standards and practices with consideration of life-cycle cost and absorptive capacities of countries
(v) Establish institutions and organization units responsible for climate impacts in the transport sector and enhance coordination among various stakeholders
(vi) Plan and implement capacity-building programs for government officials
(vii) Mobilize additional resources through internal and external sources.

It can be argued that the issues of climate change have not been addressed adequately in Asia. It can be further argued that the adaptation is overshadowed by mitigation which is getting much prominence in the global and national agenda. As the climate change is evident adaptation measures are needed to safeguard existing infrastructures as well as developing new transport infrastructure. Infrastructure are being developed and maintained – but the question is how can we address the likely impacts of extreme climate events more effectively? Therefore, there is strong need to incorporate climate impacts and adaptation into practice. It is difficult to quantify climate impacts as they are associated with risk, vulnerability and uncertainty. So risk assessment tools are necessary to assess the likely impacts and their occurrence. Further, there is subregional variation of climate events within Asia, for this reason, the adaption strategies and measure would be different for different geographical areas. The following section assess the impacts and list vulnerable transport infrastructure and related design parameters.

4.4 Assessment of impacts of climate change on transport

The climate prediction is not uniform for all parts of Asia therefore the scale of impacts on transport infrastructure depends on the severity of climate events and the local topography, terrain, and natural conditions. In terms of impacts assessment also the mitigation is measurable in terms of emissions while adaptation cannot be measured. Therefore, subjective assessment has to be made based on past experience and projected climate. In many instances it may not be possible to quantify the impacts, and qualitative assessment has to be used to express the degree of impact (ADB 1996).

The transport systems in South and South-East Asia are likely to be subjected to high-intensity rain and hot weather events, those in Northern Asia and on the Tibetan Plateau are likely to be affected by increased winter precipitation, and those on the islands and in coastal areas around the Indian and Pacific Oceans will be affected by rise in sea levels. In particular, the coastal areas of Bangladesh, the Maldives, Pacific islands, and Vietnam are highly vulnerable to rises in sea levels.

The increases in temperature, rain, and flood, frequent freeze–thaw phenomena, storm surges, and a rise in sea level will affect transport infrastructure and operations. Specific impacts of climate change on transport include thermal expansion of bridge joints, the liquidation of asphalt pavements and increased maintenance of pavement due to high temperatures, overflow of side drains and cross drainage works, submersion of bridges during flooding, and inundation of coastal roads due to rise in sea level. Sometimes operation of transport system can face closures due to landslides and mudslides of slopes.

Some of the secondary impacts of climate events are traffic disruption due to flood, heavy snow and rains, difficult driving conditions, and the postponement of travel during such events. The slow driving speeds required under extreme conditions reduce the severity of accidents but the probability of accidents could increase due to slippery surfaces. Table 4.1 lists the climate events, vulnerable transport infrastructure, design parameters and potential impacts.

Table 4.1 Vulnerable infrastructure, design parameters and potential impacts

Climate event	Vulnerable infrastructure and design parameters	Potential impacts
Temperature	*Pavement:* selection and use of type 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 and structures:* selection of material, provision of expansion joints, corrosion protection *Rail tracks:* heat resistance material, rail track joints, expansion joints *Sea ports, river ports and harbours:* selection of heat resistant materials for platforms, design of sheds	Extended warm weather can cause pavement deterioration due to liquidation of bitumen, heating and thermal expansion of bridges, railway tracks and buckling of joints of steel structure. Low temperature can affect transport operations; operation and maintenance costs are likely to increase for additional snow and ice

	Airports: Pavement material, snow and ice removal plan,	removal as well as additional costs of salts to be used for snow melting.
Rainfall	*Bridges and culverts:* flood estimation, return period, design discharge, high flood level, 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 and rail:* subsurface drains, catch drains, *Slopes:* slope protection and stabilization *Pavement:* increase surface camber for quick removal of surface water, frequency of maintenance, design of base and subbase, and material selection *Airport:* Drainage capacity, flood barrier	Increased intensity of summer and winter precipitation would create floods, affect drainage, road pavement, airport runways, driving condition and visibility, affect bridges and culverts waterways and clearance, damage bridges and culverts foundation due to scouring, affect road, rail, airport, ports and harbours, water transport channels, damage bridges foundation due to scoring. Rainfall can trigger landslides and mudslides in mountainous area and can blocks transport system.
Storms and storm surges	*Drains and cross drains:* capacity enhancement, *Bridges and foundation:* river bank protection, foundation, high flood level, frequency and intensity of rains for design *Road and rail embankment:* increase height, protection *Traffic and information signs:* wind load, structural design, foundation, corrosion protection *Sea ports, river ports and harbours:* design for storm and surge action *Water transport:* Free board and overhead clearance, dredging, flood protection at sea entrance *Airport:* Wind direction, airport runway alignment	Rainfall and winds associated with storm/cyclone can create flooding, inundation of embankments, and affect roads, rail and airports and water transport. Disrupt traffic safety and emergency evacuation operations, affect traffic boards and information signs.
Sea level rise	*Coastal road and rail:* protection wall, additional warning signs, realignment of road and rail sections to higher areas, edge strengthening *Sea ports, river ports and harbours:* height of platform, protection work	Rise in sea level will affect coastal roads, railways, port and harbour, airport near coastal area, marine transport in the affected areas., may be need to realign or abandon the transport system in affected areas.

A closer look at the Table 4.1 indicates that the rainfall, storm and storm surges are most destructive climate events affecting most infrastructure of the transport system. Therefore, appropriate consideration to the corresponding design parameters has to be given while planning, designing and maintenance of the transportation system. This would increase their serviceability and life.

The following section discusses adaptation strategies and measures required to safeguard transport infrastructure from the potential impacts of climate change.

4.5 Adaptation strategies

Two types of adaptation strategies would be required to safeguard transport infrastructure. Firstly to address the vulnerability and risk of damage of existing infrastructure and secondly planning, designing and developing new infrastructure taking into account of likely impacts of climate change. In order to achieve those strategic and policy level decision and action would be required. Once the strategic policy decision are made on how to respond and intervene to the climate events, then the different level organizational unit and project should implement those. The following can serve as a check list of actions:

(i) Strategic policy decisions in response to likely climate events and impacts;
(ii) Raise awareness of climate events and impacts at all level in the organization, as well as general public;
(iii) Make rational decision based on design review, life-cycle costing of planned measures;
(iv) Create institutions, if necessary, to ensure effective implementation and coordination;
(v) Commission specific studies to assess impacts to the vulnerable infrastructure and risky infrastructure.

Different types of impacts would need different adaptation strategies and measures for overcoming the impacts of climate change on vulnerable infrastructure components. OECD has modelled that each £ 1 spent on climate change adaptation delivers four times its values in terms of potential damage avoided (de Bruin et al. 2009).

The lack of polices and guidelines and where the policies and guidelines were existing lack of implementation was evident from the survey. Therefore, while developing adaption strategies, every aspect of development and operation of transport system, such as planning, design, construction, operation, and maintenance, need to be considered. Many projects and initiatives have targets that seek to reduce climate-change-induced risk and vulnerability. Because forecasts are uncertain, we need to use a risk-assessment approach for adaptation. In most cases, risk is assessed as low, medium, high, or very high.

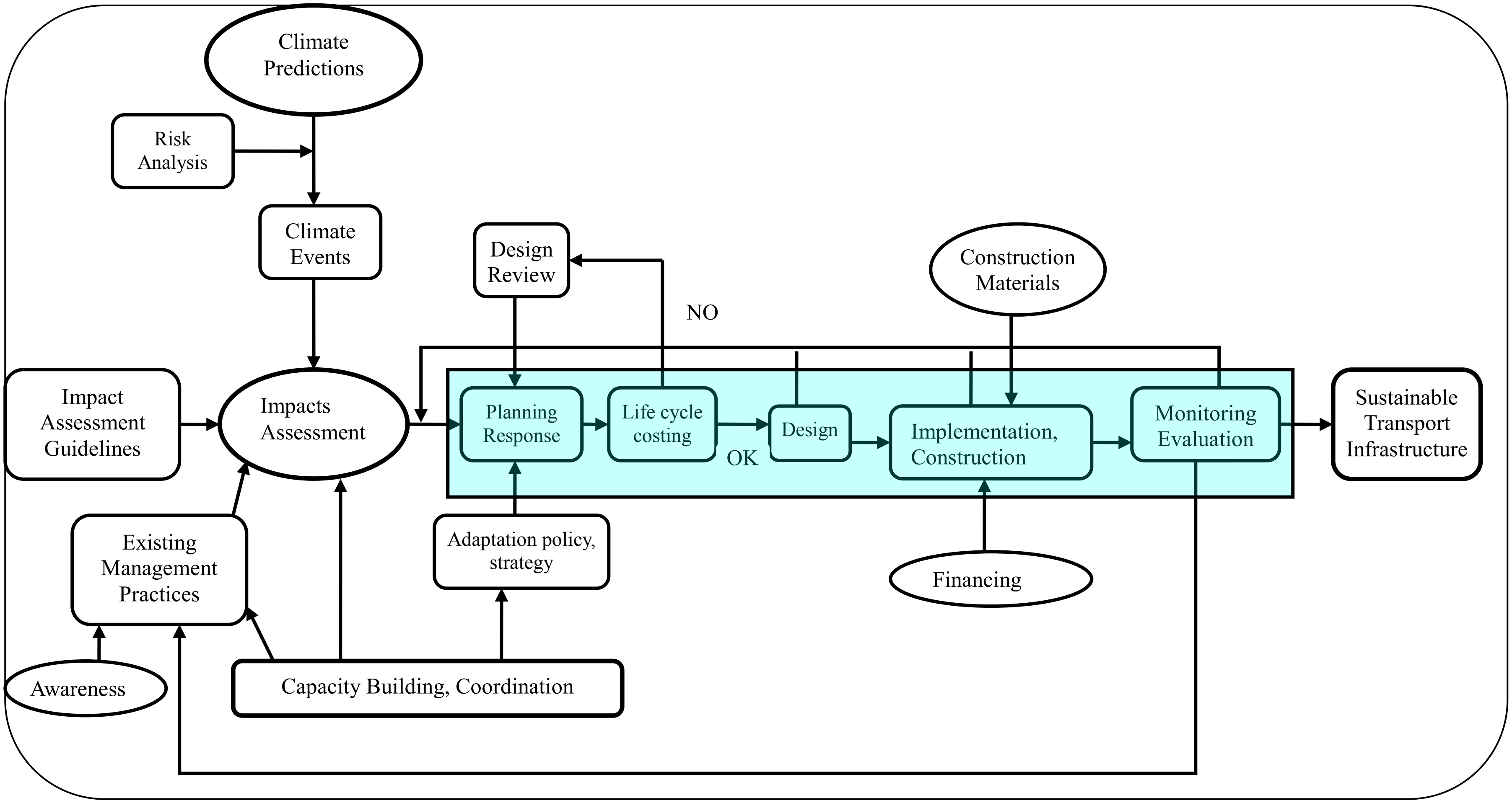
Table 4.2 shows the adaptation options, strategies, and policy measures for the transport sector. There is a strong need to initiate detail climate impact assessments and adaptation studies to generate new knowledge and provide reference and guidelines for future studies.

Table 4.2 Adaptation options and policy framework

Options/strategy	Policy frameworks	Constrains	Opportunities
Realignment/relocation; design standards and planning for transport and other infrastructure to cope with warming and drainage	Integrating climate change consideration into national transport policy; investment in Research and Development for special situations, e.g. permafrost areas	Financial and technological barriers; availability of less vulnerable routes	Improved technologies and integration with key sectors (e.g. energy)

Source: Adapted from IPCC (2007)

Figure 5.10 shows a conceptual framework of the adaptation process. The process starts with the prediction of climate events and then assessment of the likely impacts using risk analysis and impact-assessment guidelines. Then an appropriate response is planned and evaluated using life-cycle assessment. If the cost is feasible, then it passes to design, implementation, monitoring, and evaluation processes. The adaptation process within the shaded area of Figure 4.10 is actually an iterative process involving planning responses, life-cycle costing, design, implementation, construction, monitoring, and evaluation. The final objective of the adaptation process is to have sustainable transport infrastructure. The whole process is supported by adaptation policy and strategy, capacity building, and coordination.



Source: Adapted from Smit and Pilifosova, 2001

Figure 4.10 Conceptual framework of adaptation process

4.5.1 Development and implementation of adaptation strategy

It is clear that the climate change impacts affect all stage of development planning, design, construction, operation and maintenance of transport infrastructure and systems. Owing to the fact it is difficult to measure the impacts risk analysis based assessment should be done based on the past experience. Further, a paradigm shift in strategic planning is essential in order to focus on adaption and not be carried away by too much focus and attention on mitigation. Coordination among different sector and level of administration is essential. It needs some lead time to plan adaptation measures. The focus should not be only on physical infrastructure but also policies, guidelines and by-laws can also help the adaptation process. One thing is clear while investment in mitigation leads to global benefits, in case of adaptation the investment is local and the benefits are also local as well.

Strategic environmental assessment (SEA) and environmental impact assessment (EIA) can help in developing adaptation strategies and its implementation. Firstly, the scope of SEA and EIA should be extended to cover climate change impacts. Adaptation measure to the impacts of climate change for infrastructure should be effective, efficient, equitable and evidence based (DEFRA 2011). Strategic decision and policies are required with respect to planning and design such as how to incorporate risk factor in design, and considering life cycle costing for safeguarding vulnerable infrastructure or planning new infrastructure. Once the strategic decision are made these needs to be implemented and followed through at all levels in the institutions such as at the policy, prorgamme, planning and design and project level implementation that actually implements decision relating to construction and maintenance activities.

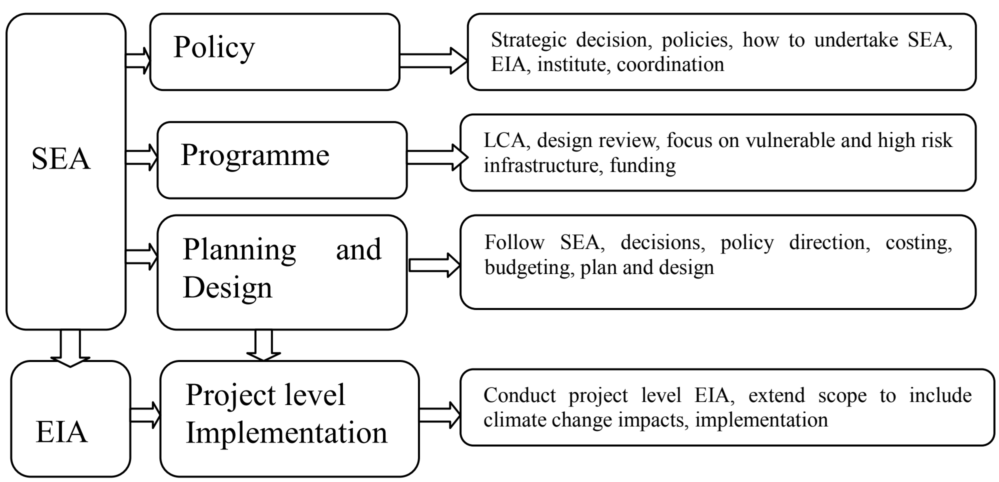


Figure 4.11 SEA and EIA policy framework

Figure 4.11 shows SEA and EIA policy framework. The following section further elaborates the key elements adaption strategy that includes: (i) Advocacy and awareness of climate change impacts; (ii) Strategic environmental assessment (SEA) and environmental impact assessment (EIA) guidelines for mainstreaming adaptation; (iii) Planning and designing of adaptation measures; (iv) Life cycle costing; and (v) Institutional set up and coordination.

(i) Advocacy and awareness of climate change impacts

Despite numerous global research and efforts in tackling the issues of climate change, the level of understanding and coordination has yet to be matched with the requirement. In majority of developing Asian countries greater awareness among all stakeholders is essential. The awareness initiative should target all professional, policy makers, technical and politicians and private sector consultants and contractors working in the transport sector. Asia needs to learn from experience of the other region. One of the important aspects of adaptation is to streamlining responses to climate change policy in development planning.

(ii) Strategic environmental assessment (SEA) and EIA guidelines

The environmental impact assessment process is well recognized and followed in Asia while designing and implementing a project. The current practice is to assess the potential environmental impacts of projects and mitigate and monitor the identified impacts during construction and operation. This impact assessment and adaption process should also take into account the risks; uncertainty and vulnerability of climate change and incorporate the effect of predicted climate events into project design. Impacts quantification involves expressing the expected magnitude of each impact in terms of appropriate quantitative physical units. Although there are some initiatives by donors to introduce guidelines on climate change and adaptation- they are general and not sector specific. It is felt that there is a need to have comprehensive adaptation guidelines for the transport sector. As transport infrastructure needs very high investment – a thorough analysis following a prescribed/suggested process would ensure 'fit for purpose' for intended life time. Therefore, the existing SEA/EIA guidelines need to be extended to cover climate change considerations and adaptation.

(iii) Planning and designing of adaptation measures

Incorporating new standards is relatively easy while planning new infrastructure. The only issue would be to look at cost implication. There would be very little additional investment to incorporate design to adapt to climate changes. In many cases it is economically feasible to design infrastructure components such as bridges, drainage, slope protection walls- considering impacts of climate change and related design parameters. It may be beneficial to review the design life of various components of the transport infrastructure. In some cases, current design standards may not be sufficient to accommodate climate change and there is the need to develop new design standards to address future climate conditions. Therefore, it may be a right time to initiate debate on the review of design parameters in Asia. Projects in highly vulnerable locations should be built with higher standards.

It is also necessary plan and design maintenance of transport infrastructure considering the climate events. It may include the increase the frequency of inspection and periodic maintenance of vulnerable infrastructure such as pavement, drains, expansion joints, bearings, foundations, and structure of steel bridges, coastal infrastructure. Further selection of suitable construction material such as bitumen, still, porous material for drains, also helps to withstand the impacts.

(iv) Life-cycle costing

Adaptation can add costs, but not adapting can be more costly. One adaptation strategy is to make infrastructure more robust against the economic cost of failure. Costing is a key factor in deciding adaptation measures. How safe and strong should the infrastructure really be and at what cost? Therefore, it is clear that the benefits of planning adaptation and maintenance well in advance are greater. The design of adaptation progamme must be based on comparison of cost avoided with costs of adaptation. Appropriate consideration of potential weather events in planning, designing and maintenance of transportation system would increase their serviceability and life.

(v) Institutional set up and coordination

It may be necessary to establish institutions and organization units responsible for climate impacts in the transport sector and enhance coordination among various stakeholders. As the impacts of climate change are widespread proper coordination and planning of adaptation measures are essential. The adaption measures are site specific and localized coordination and collaboration is essential with central, regional and local agencies are required to implement adaptation measures. The region's developing countries needs qualified professionals. Planning and implementation of capacity-building programs for government officials and professionals would help in assessing climate change impacts and implementation adaptation strategies.

Further, as transportation system is vital for evacuation planning and emergency response, more frequent monitoring of infrastructure condition during these events would be required. The transport providers should also be integrated to the emergency response team and should receive advance weather warnings so as predict potential failure and plan appropriate response to safeguard the infrastructure, warn public to stay away from the road as well as to facilitate evacuation and emergency response.

4.5.2 Financing adaptation

Many survey respondents have sought technical and financial support to initiate adaptation and capacity-building projects in the transport sector in Asia. Under the framework of the UNFCCC and the Kyoto Protocol funding support for developing countries, least developed countries and countries with economies in transition are to be made available through the Global Environment Facility (GEF), the Special Climate Change Fund (SCCF), the Least Developed Country Fund (LDCF) and the Adaptation Fund (AF). However, there are very few adaptation projects in transport sector within the Clean Development Mechanism (CDM) and GEF (Wright and Fulton 2005). Since 1999, the GEF has financed 37 transport sector projects with total GEF support of US$ 201 million. Although, the GEF has 7 transport projects covering 32 cities, most of the project focus on GHG emissions. Not a single project concerns adaptation measures because GEF projects need to demonstrate CO_2 reduction potential (GEF 2009). Many of these projects focus on sustainable transport, new fuels, and public transport and not a single project relates to transport infrastructure. National Adaptation Programme of Actions (NAPA) does not even class transport as a sector. Transport is grouped within infrastructure sector and sometimes fuel related transport projects are grouped within energy sector. Countries should look at the ways to initiate more transport projects under CDM. The Asian Development Bank has recently established climate change fund. Project proponents and countries may approach international financing institutions and bilateral donors to seek technical and financial resources for planning and implementation of climate change adaptation measures on transport. Adapting to climate change takes time and additional financial and human resources are required to implement adaptation strategies. There has been long debate on financing climate change initiatives- the developed nations need to fulfill their commitments by providing financial and technical support to the developing countries.

4.6 Adaptation strategies for dry port development

The adaptation strategy and framework outlined is section 4.5 is now applied to a case of dry port development. Sustainability and safeguarding dry port infrastructure from impact of climate change is very important as they are an integral part of an intermodal transport system. First and foremost information related to climate predictions in the area vicinity of the proposed location needs to be collected. The probability of occurrence of these climate events need to be considered in planning, design and construction of dry ports. The identification of structurally sound and safe location is also a challenge. Once the site is finalized then the design process starts considering the freight volume and transport modes considered. As the connectivity to the seaports from dry port is important, the overall condition and likely impacts of climate events on the transport infrastructure need to be assessed as well giving detail attention to the vulnerable location and infrastructure sections. Transport infrastructure includes roads, railways, and inland waterways and could belong to different government agencies as well as service providers, therefore, coordination with these institutions is essential to safeguard those and ensure less interruption during operation.

The common infrastructure and facilities a dry port should have are general cargo and container area, ware house, railway siding, truck holding area, customs clearance and inspection area, administrative buildings, security gate, and specialize cargoes area. Depending on the types of commodity expected to be handled such oil, cement, raw materials, etc. the dry port would need separate areas to handle these. The layout of these facilities should be planned such a way that would ensure smooth operation of dry ports.

There should be clear strategic environmental assessment (SEA) of the dry port development that would develop and finalize strategies such as guidelines on adaptation policy, design and planning response in case of likely impacts in developing new dry port. Life cycle costing can be applied to look at trade-off between various designs of infrastructure components and its costs. Once the SEA is finalized, project level EIA should be done to study the forecast climate events, assess likely impacts considering each infrastructure during construction and operation. Planning appropriate adaptation measures and implementation of those during construction and operation of dry ports are necessary. One important aspect of adaptation is to ensure periodic monitoring and maintenance of key infrastructure.

The concept of the dry port is to bring the facilities offered by seaport in inland area; the coastal areas where the ports are located are usually vulnerable to climate change impacts such as sea level rises and storms. Development of dry ports at secure and safe inland location can be considered as an adaptation measure to safeguard these infrastructures from potential damage by the climate events. Therefore, while deciding the location of dry ports the suitability of inland location to withstand impact of climate events need to be considered. If we invest in adaption measures the cost are local and benefits are also local

Even developing dry port in secure inland areas the likely impacts from excessive rain, potential flooding, cyclones, heat and snow need to be considered. The scale of impacts depends on the location. However, some adaptation measures that can be incorporated during planning and design stages are: (i) increasing plinth level of the cargoes, container and warehouse to safeguard from flooding; (ii) construction of adequate cross drainage, drainage and dykes along the periphery of the dry ports to avoid rush of flood waters and flooding; (iii) ensue the structural safety of covered warehouse and cargo area in case of storms and cyclone, as these would be vulnerable due to long span and height; and (iv) selection of suitable construction materials for road pavement and container yard within dry port to withstand the heat as well as cold temperature.

Provision of facilities offered by ports in inland and hinterland area is one of the key concepts of development of dry ports. Such concept and their development in suitable and secure area would contribute to the overall efforts of climate change adaptation. This would bring about economic development in inland area as well as safeguard transport infrastructure from risk to be affected by rising sea level and sea storms. The implementation of adaptation strategies and measures for the development of dry port and operation can safeguard it from likely impacts of climate events.

4.7 Results and discussions

Transport infrastructure and operations are affected by climate events such as extreme rainfall, elevated temperature, rises in sea levels, and storm surge. Despite global efforts in addressing climate change, Asia still lags in formulation and implementation of adaptation strategies for climate change impacts in the transport sector. Further, the survey showed the need to plan and design transport infrastructure such as bridges, culverts, drains and cross drains, pavements, and coastal roads with consideration of the likely impacts of climate change. The variation in climate events' intensity and the degree of impact in different Asian subregions indicates the need for different adaptation strategies and policies. The assessment also identified the need to increase the awareness level of the general public and to enhance the awareness of policymakers. The need to review the design standards to incorporate the likely impacts of climate change and the need for impact-assessment guidelines have also been identified. Policy and implementation gaps have been identified and these need to be addressed in order to mainstream climate change impacts, adaptation, and vulnerability issues and consider life-cycle costs. There is clear need for greater collaboration among agencies, and, in many cases, the need to establish organizational units and branches responsible for planning and implementing adaptation strategies. The issues of funding and technical support required to plan and implement adaptation strategies also emerged as a major cause of concern for developing countries.

In order to develop sustainable transport infrastructure, the most important consideration is to assess the likely impacts of climate change based on available predictions and incorporate these assessments in the planning process. Considering that many Asian countries still lack clear impact assessment guidelines, it is advisable and important to extend SEA/EIA guidelines to take account of the risk and uncertainty of climate change and incorporate the predicted climate events into project design. Climate change impact-assessment guidelines would help to systematically evaluate the impacts. The next step is to review existing policies, design standards, and practices. Because adaptation measures in transport are costly, life-cycle costing of proposed adaptation measures would be useful to select appropriate and feasible alternatives. In addition, because impacts are widespread, coordination at national, regional, and local levels is essential for implementation of adaptation strategies. Increased levels of awareness and coordination among all Asian stakeholders are essential to develop sustainable transport. Country-specific adaptation studies are required to develop adaptation strategies to plan and sustainable transport infrastructure.

Developing dry ports in secure inland areas, strategic decisions and policies at the planning and design level can contribute greatly to prolong the life of dry ports and ensure their sustainable operation. The limited literature on transport and climate change studies in Asia indicates that further research is needed in country-specific assessment and quantification of impacts and adaptation strategies for developing robust and sustainable transport infrastructure.

4.8 Chapter summary

The chapter outlined climate predictions for Asia, the perception of policy makers on climate change and proposed adaptation strategies for the transport sector. Some of the key messages are the need to consider climate impacts in design, taking life cycle assessment approach and the need to develop sustainable transport infrastructure to withstand the likely impacts of weather events. Nee to enhance awareness of both policy makers and general public also came out as an important issue. It also elaborated on some of the resources available for transport and climate change. Utilization of available resources in an efficient ways also is very important in this respect capacity of policy makers and project managers in implementing policies and projects related to transport and climate change need to be enhance. This chapter dealt with adaptation aspect of developing sustainable transport and dry ports. The next chapter focuses on other aspect of sustainability of transport – mitigation and looks at the development of dry ports from environmental perspective.

CHAPTER 5

CASE STUDIES OF THE DEVELOPMENT OF DRY PORTS IN ASIA[5]

5.1 Introduction

In order to promote intermodal transport, it is essential to develop transport links, service and nodes, which include ports, airports, river ports, and inland dry ports, as well as to improve the efficiency of transport services. Intermodal transport nodes provide opportunities for a modal shift. Development of dry ports can enhance consolidation and distribution of goods. Various studies have focused on development of dry ports, inland terminals, and intermodal transport in Europe and developed countries (Rodrigue et al. 2010 and Caris et al. 2008). Therefore, development of dry port and identifying strategic location that could enhance environmental benefits in Asia need to be further explored.

This chapter presents details on the collection and analysis of case studies of dry ports development in Asia. Finally, it presents key findings through a comparison of the cases.

5.2 Collection of case studies

Intermodal transport can facilitate modal shifts from one mode to another. The planning and development of freight terminals, freight villages, dry ports, and inland container depots (ICDs) can extend the reach of the rail mode through intermodal services. In this respect, in order to review the development of dry ports in Asia from environmental perspective the following case studies have been collected. Site visits to Uiwang, Birgunj, Alashankou, Navoi and Kamalapur dry ports were undertaken. The dates of the visits are indicated within parentheses.

i. Alashankou, Horgos dry port, China (16-17 June 2010);
ii. Uiwang ICD, South Korea (16 July 2010);
iii. Navoi International Logistics Centre, Uzbekistan (26 Nov. 2010);
iv. Kamalapur ICD Dhaka, Bangladesh (14 September 2011); and
v. Birgunj Inland Container Depot, Nepal (17 September 2011).

Information for the following dry ports were collected during a regional meeting on dry ports held in Bangkok during 1-3 November 2010 and from other secondary sources.

i. Lat Krabang ICD, Thailand;
ii. Dry port development in India; and
iii. Cikarang Dry Port, Indonesia.

[5] Part of this chapter was published as Hanaoka, S. and Madan B. Regmi, (2011), Promoting intermodal freight transport through the development of dry ports in Asia: An environmental perspective, Journal of International Association of Traffic and Safety Sciences (IATSS) Research, Vol.35, No.1, 2011, 16-23. The paper is available from: (http://www.sciencedirect.com/science/article/pii/S0386111211000148).

5.3 Case studies of development of dry ports in Asia

Countries in Asia are at different stages in the development of dry ports. At present, both road- and rail-based intermodal dry ports near production and industrial centers are being developed to extend the reach of intermodal transport and to effectively consolidate and distribute cargoes. Selected case studies of the development and operation of dry ports in Asia is outlined and key financial, operational, environmental, regulatory and institutional factors involved in their development and operation are discussed in the following section. Key findings from these case studies can provide guidance for transport and logistics policy makers and professionals in planning, development and operation of such dry ports.

5.3.1 Uiwang ICD, South Korea

Rapid growth in South Korea's export and import volumes has led to an expansion of the nation's ports. The pace of port expansion, however, was slower than the growth of trade: this led to congestion at gateway ports such as Busan, Gwangyang, and Inchon, which handled the majority of South Korea's foreign trade. In response, in 1980, the government initiated a policy to develop inland logistics centers.

The Uiwang ICD, which is located 25 km from Seoul, was developed by a public-private partnership (PPP) in 1993. The Korean Rail Road Company and private transportation companies have invested in the Uiwang ICD. It has a capacity of 1.3 million TEUs and spans 417,000 m^2. In addition to private-sector facilities and operating companies, customs, food inspection, plant quarantine, and railway operations are located within the ICD. Shippers send goods by road to the ICD, where they are consolidated and sent to seaports by rail. With a rail capacity of 36 trains per day, the ICD utilizes both modes of transport, which helps to ease road congestion and enables the facility to serve as a clearance depot. Figure 5.1 shows the container yard and block train at Uiwang ICD.

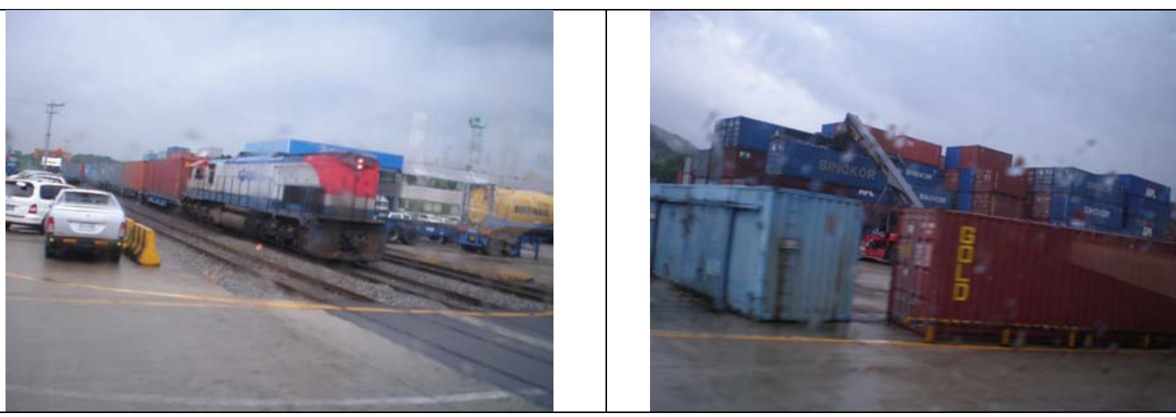
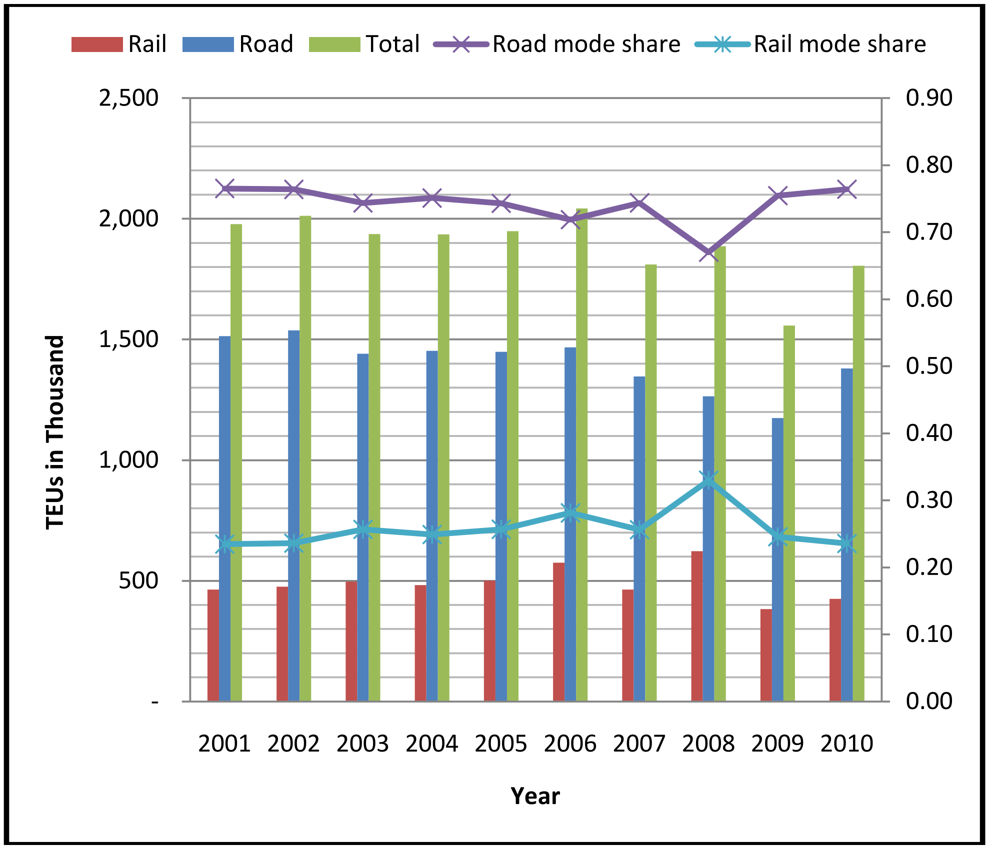


Figure 5.1 Block train and container yard, Uiwang ICD

Figure 5.2 shows the containers handled at Uiwang ICD, which exceeded 2 million TEU in 2006. As can be seen in the Figure 5.2, there was a decrease in the volume of containers handled after 2008 due to the economic recession. Further, the road mode share was approximately 75%, except for a drop in 2008. Figure 5.2 also shows that the rail mode share of throughput handled by the ICD was about 25% in 2010, even though the ICD was running over capacity. The rail share increased to about 35% in 2008 but again dropped. This use of railways for transport to/from the ICD to seaports has helped to ease road traffic congestion and reduce vehicle emissions. An expansion of the ICD's and railway's capacity would further enhance the environmental benefits, as would an increase in the rail mode share of freight.



Source: Uiwang ICD, 2011

Figure 5.2 Container throughput at Uiwang ICD and mode share of road and rail

The Ministry of Land, Transport and Maritime Affairs (MLTM) is the regulatory authority responsible for the planning, construction, and management of dry ports in South Korea. MLTM encourages private sector investment in the development of dry ports and logistics centers. Large-scale infrastructure project proposals from the private sector are reviewed by the Public and Private Infrastructure Investment Management Center (PIMAC) to determine whether they are consistent with the government's long-term plans and investment priorities. The government provides some support for the development of dry ports by assuming part of the land acquisition and project costs. Infrastructure projects under PPP are either selected by the government or proposed by the private sector. Uiwang ICD presents an interesting case of market-driven dry port development that uses PPP for both financing and the improvement of operational efficiency. Government logistics policies and PIMAC have played a supportive role in this development.

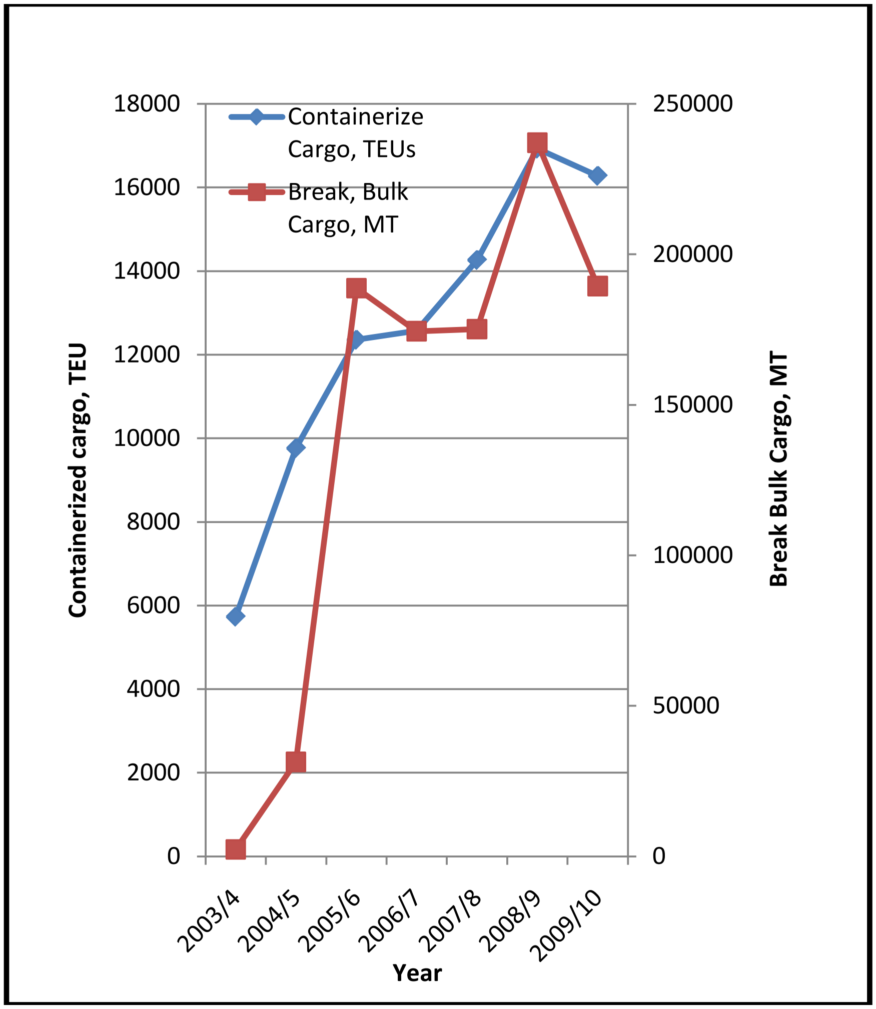
5.3.2 Birgunj ICD, Nepal

The Birgunj ICD was developed by the government of Nepal with the support of the World Bank. It has a 12 km rail link to the ICD from the Raxaul railhead near the border with India, and it connects further to the Kolkata/Haldia ports in India. The length of the road from Kolkata, India, is 924 km, and that of the railway is 704 km. The ICD facilities include a broad gauge railway yard with six full-length lines, a container stacking yard, a covered container freight station, goods sheds, and parking space. It is equipped with the automated system for customs data (ASYCUDA). Figure 5.3 shows the container yard and block train at Birgunj ICD. Since majority of rail links are in India, it took the government of Nepal some time to conclude a rail service agreement with India for the operation of the dry port. The Birgunj ICD, which was commissioned in July 2004, but whose operations began two years later, is leased to the private sector for operation. It now handles containers, tank wagons for liquid cargo, and flat wagons for bilateral break-bulk cargo, following amendments that were made to the service agreement.

Figure 5.3 Block train and containers at Birgunj ICD, Nepal

The Nepal Intermodal Transport Development Board (NITDB), which has representatives from the public as well as the private sector, is the regulatory body overseeing all dry ports/ICDs in Nepal. As envisaged in Trade Policy 2009, the Nepal Intermodal Transport Development Authority (NITDA) is planned to be established to regulate operational issues, including the issuance of licenses for the development and management of dry ports, container freight stations, and integrated customs points in the country.

The Birgunj ICD currently receives an average of around 15–16 freight trains per month. The volume of container and cargo handled there is shown in Figure 5.4 (Regmi 2011). The sharp increase in volume for break-bulk and container cargo from 2004/5 to 2005/6 was due to the expansion of the railway service agreement to allow covered wagons and bilateral trade through the dry port. Prior to this, only transit trade with containers had been handled at the ICD. The drop in volume during 2009/10 can be attributed to the global economic recession.



Source: Regmi 2010

Figure 5.4 Cargo handled at Birgunj ICD

Figure 5.4 shows that the freight handled at Birgunj ICD in 2008/09 comprised 16,928 TEU (equivalent to 406,272 MT[6]) and 237,104 MT of cargo. The following scenario illustrates the emissions reduction potential of the rail-based Birgunj ICD: had there been no dry port, all freight from Kolkata[7] would have been transported to the dry port by heavy goods vehicle (HGV). Freight carried by rail emits much less CO_2 compared to freight being transported by (HGV. For example, an average 28.3 g of CO_2 emission per tonne-km of rail freight, 118.6 g for HGV are in use in UK (DEFRA 2009). Using these emissions factors, the resulting CO_2 savings would have been 57,687 MT for 2008/9, which accounts for about 82% of the total road emissions. Table 5.1 shows resulting CO_2 emissions savings from development of rail based dry port in Birgunj, Nepal.

[6] Using maximum allowed weight, 1 TEU = 24 MT.

[7] Kolkata–Birgunj: road distance, 924 km; railway distance, 704 km.

Table 5.1: Assessment of CO_2 emissions at Birgunj Dry Port, Nepal

Mode	Length Km	Freight TEU	Freight MT	Eq. Freight, MT	T-km	CO_2 Emissions, MT	
Rail	704	16,928	237,104	643,376	452,936,704	12,818	(A)
Road	924	16,928	237,104	643,376	594,479,424	70,505	(B)
			Saving in CO_2 Emissions (B-A)			**57,687**	

The lessons learned from the case of Nepal show that it is relatively easy to develop an ICD infrastructure but that more effort is required to put it into operation. In any event, this ICD is a unique case, in the sense that it is located near the border, its main railway connection is from the Kolkata port in India, and most of its freight route is in India. The conclusion and expansion of the railway service agreement to include open break-bulk and freight wagons took more time than anticipated. Therefore, it is worth considering operational issues during the development of infrastructure. The case of this Birgunj ICD underscores the importance of operational and facilitation issues, and the need to initiate and discuss operational agreements in advance.

Now, adjacent to the Birgunj dry port/ICD an integrated border post is being developed. This integrated check post would process clearance of goods as well as passenger. The construction of integrated check post has already been started. A field visit to see the operation of the Birgunj dry port and observe initial construction of the integrated post was undertaken on 17 September 2011.

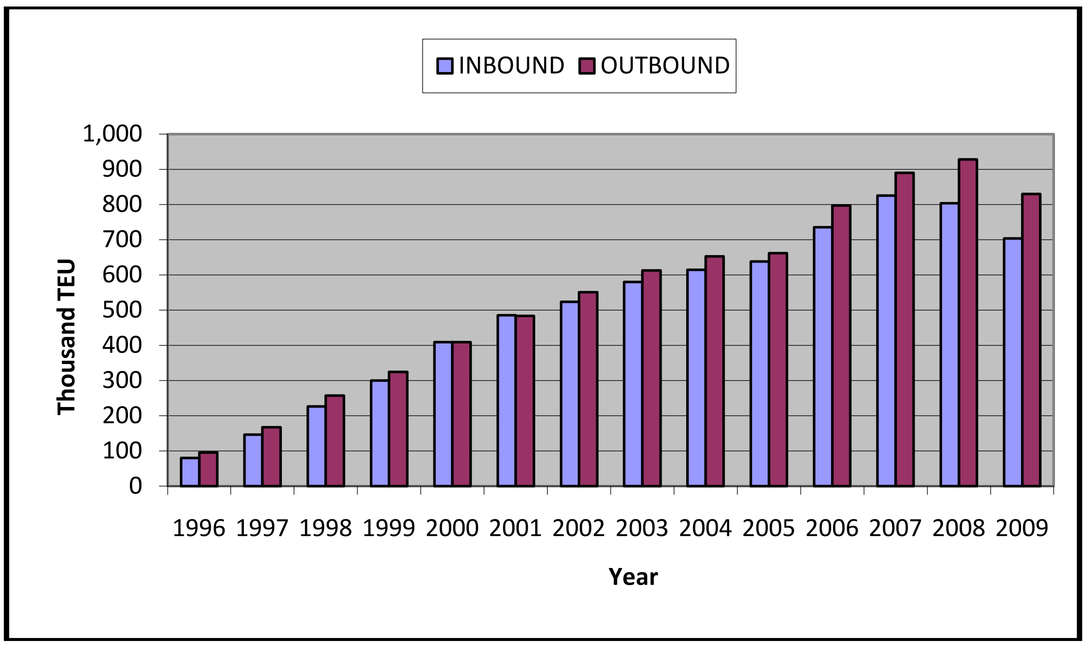
Other dry ports in Nepal are in Biratnagar, Bhairahawa, and Kakarbhitta, which are near the India border, and at Kodari, near the Chinese border. Recent initiatives to promote intermodal transport and railway in Nepal includes ongoing feasibility study of an east-west railway, a 60-km-long Kathmandu-Birgunj railway, and connections to the four railheads in India. Furthermore, talks are underway to extend the railway line from Lhasa in the Tibet region of China to the dry port at Kodari and further south to Kathmandu.

5.3.3 Lat Krabang ICD, Thailand

The Lat Krabang ICD was developed by the State Railway of Thailand (SRT) and operations started in 1996. It is located about 27 km east of Bangkok and 118 km north of Laem Chabang Port, with cargo carried by both railway and road between the Lat Krabang ICD and Laem Chabang Port. Terminal operations are managed by six private-sector concessionaires who provide services related to cargo consolidation, distribution, warehousing, customs clearance, and empty container storage. Figure 5.5 shows container block train and yard at the Lat Krabang ICD.

Figure 5.5 Block train being assembled for Lat Krabang and containers

Thailand is giving priority to the development of dry ports in order to help shift the movement of freight from road-based transport to intermodal transport. The existing Lat Krabang ICD has a full electronic data interchange (EDI) link and handled around 1.7 million TEUs in 2008, far more than its initial design capacity of 500,000 TEU. Because of the resulting congestion, many containers from Laem Chabang Port are now bypassing the Lat Krabang ICD and proceeding directly to external facilities for consolidation and deconsolidation.

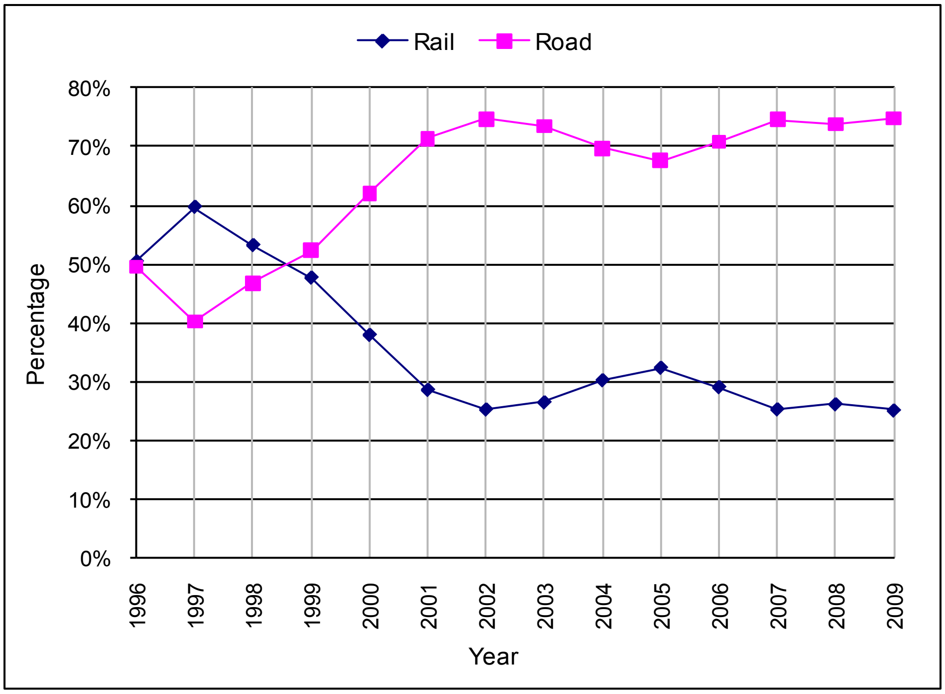


Source: Ratanachinda 2010

Figure 5.6 Containers handled at Lat Krabang ICD

Figure 5.6 shows the continuous increase in containers handled at the Lat Krabang ICD. Figure 5.7 shows the modal share of containers handled by truck and rail. Although it was designed for a rail-to-road mode share ratio of 40:60, the rail share has been decreasing due to limited rail link capacity, congestion at the ICD, and the greater flexibility of road transport. On weekdays, 26 freight trains with 30 bogie container flat wagons capable of carrying 60 TEUs operate between

Laem Chabang Port and Lat Krabang ICD.



Source: Ratanachinda 2010

Figure 5.7 Mode share of containers handled at Lat Krabang ICD

Figure 5.7 shows that the rail mode share of the throughput handled by the ICD was about 25% in 2009 (Ratanachinda 2010), contributing to an overall reduction in congestion and emissions, since this reduced throughput would otherwise have been transported by road. The ICD is currently running at nearly twice its capacity. Therefore, SRT's planned expansion of the ICD capacity can positively contribute further to have environmental benefits.

In addition to the expansion of the Lat Krabang ICD, SRT is planning construction of new dry ports to enhance the country's logistics capabilities and to encourage a modal shift from road transport to the more environmentally friendly rail and water transport.

5.3.4 Dry port development in China

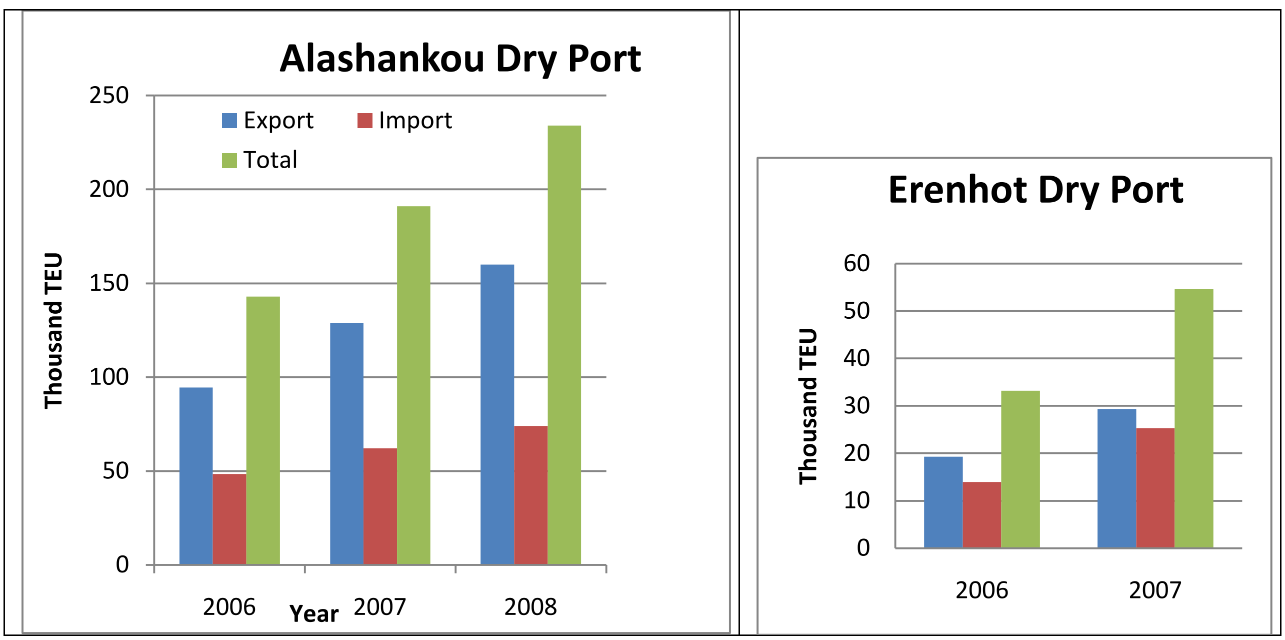
China is developing 18 large inland container rail transfer and logistics distribution centers (Wu 2009) as part of its "Go West" strategy to encourage investment in, and the industrialization of, the country's interior. The China Railway Container Transport Center (CRCTC) was established by the Ministry of Railways as a container rail operator that can attract foreign investment. CRCTC has also attracted other companies to invest in a number of specific ventures. These facilities are operated by China United International Rail Container Co., Ltd, a special-purpose entity set up by the Ministry of Railways in 2007.

Dry ports play an important role in stimulating economic development and facilitating international trade and transport in China's central and western inland areas. In this regard, three aspects of this initiative need careful consideration: (i) the role of the national government in promotion and coordination; (ii) the development of dry port infrastructure, including other transport infrastructure that links to dry ports; and (iii) the streamlining of institutional and regulatory frameworks (ESCAP 2010c).

The Shijiazhuang dry port, with a design capacity of 205,000 TEUs per year, is one of the largest dry ports in China. This dry port has both rail and road access. Customs, inspection, and quarantine are available here. This dry port has direct links with Tianjin seaport and mainly serves as a feeder for that port.

China also has a road-based dry port in Urumqi. A number of small-scale dry port facilities are under construction near the Urumqi railway station. All these dry ports in Urumqi mainly serve markets in Xinjiang and are not used for international trade. International cargo to and from Lianyungang to Alashankou normally bypasses Urumqi.

In terms of cargo volume, Alashankou is the second largest border station in China; it connects to the Dostyk station in Kazakhstan. It can handle all types of cargo: containers, break-bulk, oil, etc. On average, the Alashankou dry port handles about 20 freight trains daily. The Erenhot dry port near the border with Zammin-Uud in Mongolia also handles containerized and bulk cargo. Figure 5.8 presents the volume of containers handled by Alashankou and Erenhot, showing growth of 36% and 52%, respectively, between 2006 and 2007.



Source: Wu 2009

Figure 5.8 Container traffic through border dry ports in China

An international free trade economic zone (FTEZ) whose aim is to attract the construction of manufacturing factories is being established in Horgos, near the border between China and Kazakhstan. A logistics center is also planned within the FTEZ. Currently, border crossing and transport at Horgos are conducted by road. The average wait-time for trucks to cross the border is 2–3 days. Around 75–100 trucks cross the border each day from China to Kazakhstan, and a similar number travel from Kazakhstan to China. Trucks from Kazakhstan that receive special permission are allowed to operate in specified areas in China. An equal number of permits are issued to Chinese trucks operating in Kazakhstan. A railway linking Jinghe, Yining, and Horgos has recently been completed. A railway connection on the Kazakhstan side from the border of Khorgos to Almaty is also being planned**.** Figure 5.9 shows Alashankou dry port and trucks crossing China-Kazakhstan border at Horgos.

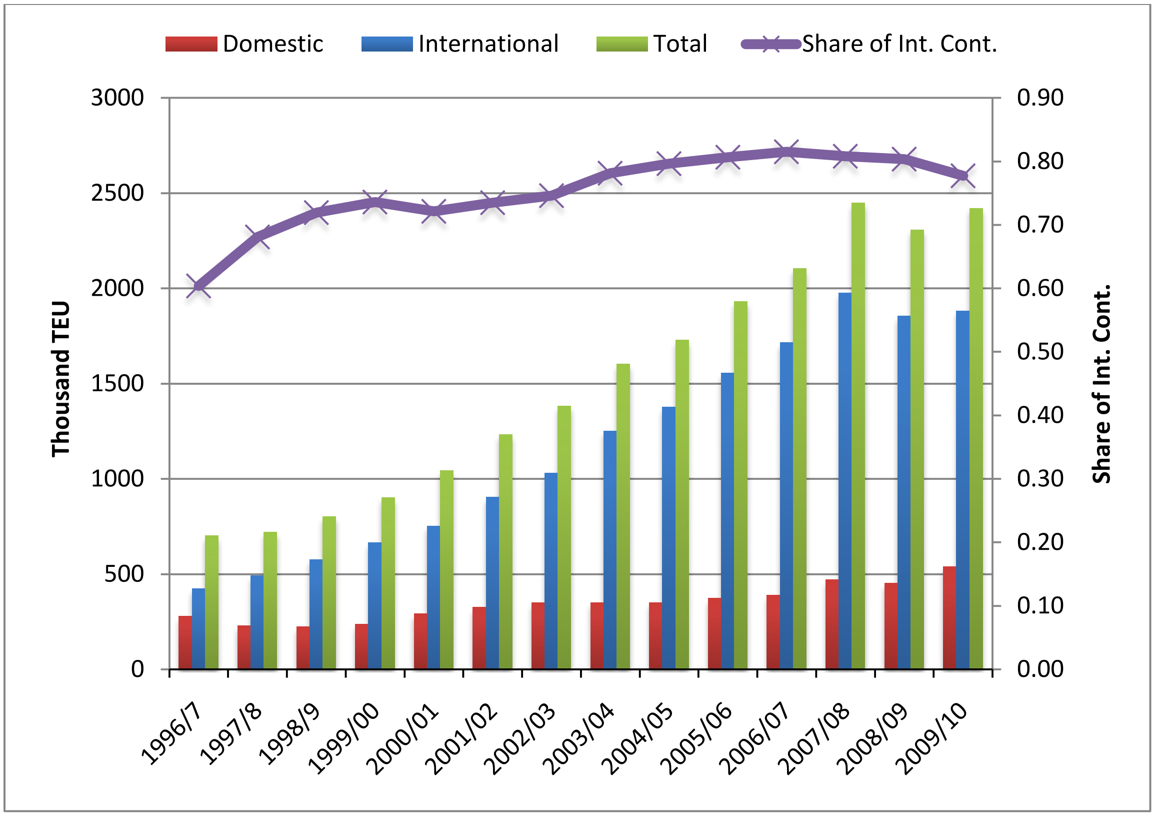
Figure 5.9 Alashankou dry port and truck near Horgos border, China

In order to improve rail freight efficiency, China has been running double-stack container train services to and from the main coastal ports on selected routes, using new specialized wagons and powerful locomotives. In 2007, Chinese Railways operated 680 double-stack trains that carried 53,161 TEU, compared to 2005, when it operated 454 trains that carried 39,437 TEU (ESCAP 2009).

Development of dry ports, improvement of railway links and efficiency of double-stack trains mentioned above would improve overall efficiency of the intermodal transport and take more share of freight and contribute to overall environmental benefits.

5.3.5 Dry port development in India

India has an extensive network of 59 ICDs, 49 of which can handle export-import. These inland dry ports provide customs clearance, warehousing, container parking, repair facilities, and office facilities. In almost all cases, these terminals are linked by rail to the Indian railway network. The operation is handled by the Container Corporation of India, Ltd. (CONCOR), a subsidiary of Indian Railways. Figure 5.10 presents the volume of containers handled by CONCOR and shows that the share of international containers has grown gradually from 60% in 1996/97 to 81% in 2007/08. The decrease in container volume beginning in 2007/08 could be due to the economic recession. CONCOR is investing in the modernization of facilities and improved efficiency by improving its fleet and developing dedicated container platforms, advanced information systems, e-Business, and the use of information and communication technology (ICT) for container tracking.



Source: CONCOR, 2011

Figure 5.10 Containers handled by CONCOR, India[8]

The Tughlakabad ICD, which is located 17 km to the southwest of Delhi, has an area of 55 hectares and is the largest rail-linked ICD in North India. It has a handling capacity of 400,000 TEUs per year. It has good links to the Mumbai and Jawaharlal Nehru ports through the Delhi–Mumbai arterial trunk corridor and national highways. The ICD is equipped with completely modern facilities that include EDI, export and import warehouses, radio-frequency identification (RFID) container tracking, and customs clearance. In 2009/10, Tughlakabad ICD handled 413,384 TEUs. Figure 5.11 shows container and block trains at Tughlakabad ICD.

Figure 5.11 Container and block train at Tughklabad ICD, India

[8] http://www.concorindia.com

India is also implementing a project to develop dedicated freight corridors with an investment of about US$10 billion. One of these is the Mumbai–Delhi corridor, which is receiving assistance from the Japanese government. This freight corridor segregates freight from passengers and be a state-of-the-art system with a high axle load and capacity (Parhi 2009).

The increasing trend of container handled at ICDs and transport to ports by railways shows overall positive environmental benefits. These environmental benefits would be further augmented when the efforts to improve operational efficiency of ICDs and dedicated freight corridors would be complete.

5.3.6 Navoi International Logistics Centre, Uzbekistan

Uzbekistan has established an international intermodal logistics centre at Navoi, situated about 350 km of south-west of Tashkent with the aim of becoming a regional transshipment hub in Central Asia. Currently, it is a predominantly air-based logistics centre serving as a consolidation hub for transport of high-value goods from Asia to Europe and vice versa. Freight service is on operation from Navoi to major destinations including Inchon, Milan, Brussels, Delhi, Mumbai, Bangkok, Frankfurt, Shanghai, Moscow and Dhaka. There are plan to extend cargo service to Istanbul, Almaty, Dubai, and Tel Aviv.

Korean Air has been engaged to manage and operate the logistics center and develop and market a business plan up to 2018. Uzbekistan Air and Korean Air operate 40 cargo flights per week. Even though sufficient cargo and freight is not generated at Navoi, it is being used as consolidating and distribution hub for transporting air cargos to Central Asia and Europe. The Navoi airport operates 24 hour and can cater for 10 heavy aircraft such as Boeing-747 per day and parking for five heavy aircraft. It has a 4,000 m × 45 m runway with instrument landing system and has a plan to develop another runway. It has capacity to process 300 tons of cargo per day (100,000 tons per year). It is capable of receiving all types of aircraft.

The new cargo terminal with capacity of storing 1,000 tons of cargo was opened in August 2010. It includes facilities like refrigeration and freezer, heating chamber, the storage area of dangerous goods, perishable foodstuffs and animals. Other facilities required for international logistic terminals are being developed such as hotel, expansion of capacity, parking areas for trucks. Administration building houses all essential services. Figure 5.12 shows railway track and cargo storage area at the Navoi logistics centre.

Figure 5.12 Navoi Logistics Centre, Uzbekistan

In 2009 it handled 26.7 thousand tons of cargo and it was estimated that the volume handled to reach to 60 thousand tons in 2010. Outside of Inchon, Navoi is the 2nd largest air fright hub in terms of cargo frequency. Navoi is aiming to be number one cargo service provider. Its central location is interesting as major cities such as Moscow, Istanbul, Tel Aviv, Dubai, Mumbai, New Delhi and Almaty are within radius of 6 hours flight time while Milan, Frankfurt, Brussels, Bangkok, Shanghai and Inchon are within 8 hours flight radius.

A free economic industrial zone (FIEZ) in Navoi was established in 2008 to attract foreign direct investment from manufacturer to produce high value cargos. The initial lease within the FIEZ is 30 years. It is an extensive 584 hectares development, which is still under construction that includes a logistics centre with an area of 40 hectares. International joint ventures with companies from Japan, South Korea and Singapore have established manufacturing factories within the zone. FIEZ provides one stop licensing and registration service including tax incentives for investment and customs incentives on equipment imports.

Navoi provides a very useful example of development of logistics centre/dry port on policy initiatives of the government and commitment of various organizations from the beginning. Examples of policies include provision of infrastructure, land lease, tax incentives for bringing FDI to the free economic zone to generate cargo and one stop service to grant business and manufacturing license, customs incentives to import equipments.

5.3.7 Cikarang Dry Port, Indonesia

Cikarang Dry Port has started operation since 2010 and is the largest and busiest dry port in Indonesia. It has an area of 200 hectare and is accessible by road and railway and serves Tanjung Priork International Port in Java province in Indonesia. It is located in Jababeka Industrial Estate[9] and is just 50 km away from the port. The dry port is developed by private sector concessionaire.

The Cikarang Dry port has state of art facilities and provides one stop services to the customers. It has integrated and automated customs clearance facilities, customs bonded area, truck pool, empty container area, logistics area and supporting services including maintenance area. It also has Customs Advance Trade System (CATS) and electronic sealing system for added security of cargoes. Banking and supporting facilities are available in the dry port. Figure 5.13 shows the Cikarang Dry Port. It is forecast to handle 168,950 TEU in 2015 and 215, 625 TEU in 2020.[10]

[9] Cikarang Dry Ports (www.cikarangdryport.com) accessed on 23 November 2011.
[10] Indonesia country report on dry ports, ESACP, 2011.

Figure 5.13 Cikarang Dry Port, Indonesia[11]

The dry port also designated as the port (point) of origin and destination having port code "IDJBK." Thus multimodal bill of loading can be issued to/from Cikarang. It handles international export and import as well as domestic distribution. Due to this many shipping lines have opened route to Cikarang Dry Port.

It provides integrated port and logistics services. It is mentioned that the use of Cikarang Dry Port offers 30% cost and 55% time saving compared to existing conventional system. From September 2011 the customs has announced implementation of the National Single Window for import and export at Cikarang Dry Port.

Although clear environmental benefits of the dry ports are yet to be seen, as it is relatively new facility, the use of integrated and automated system claim to have clear time and cost benefits to the users. Even though, railway service is available the data on mode share of cargoes coming and going out of the dry port is not yet available. Improving railway connectivity to and from dry port and its use would provide environmental benefits.

5.3.8 Kamalapur ICD, Bangladesh

Kamalapur ICD, the only ICD in Bangladesh, was established by a Presidential order in 1987 and started its operation. It has direct rail link to Chittagong Port. The length of railway from Kamalapur to Chittagong port is 320 km. The ICD has annual handling capacity of 90,000 TEU and daily handling capacity of 4067 TEU. It is owned by the Bangladesh Railway and operated by Chittagong Port Authority (CPA). The ICD is customs bounded facility and "through bill of lading" can be issued to/from the ICD. Bangladesh Railway operates two block trains every day and it takes about 12 hours. Figure 5.14 shows block train and container yard at Kamalapur ICD, Dhaka.

In terms of capacity, it has limited capacity to handle containers due to the problems associated with shortage of railway wagons and engines. Reefer containers are not handled at ICD. The ICD has container yard with an area of 449,143 sq m and container freight station with an area of 27,149 sq m. It also has container handling equipments such as rubber tired gantries, saddle

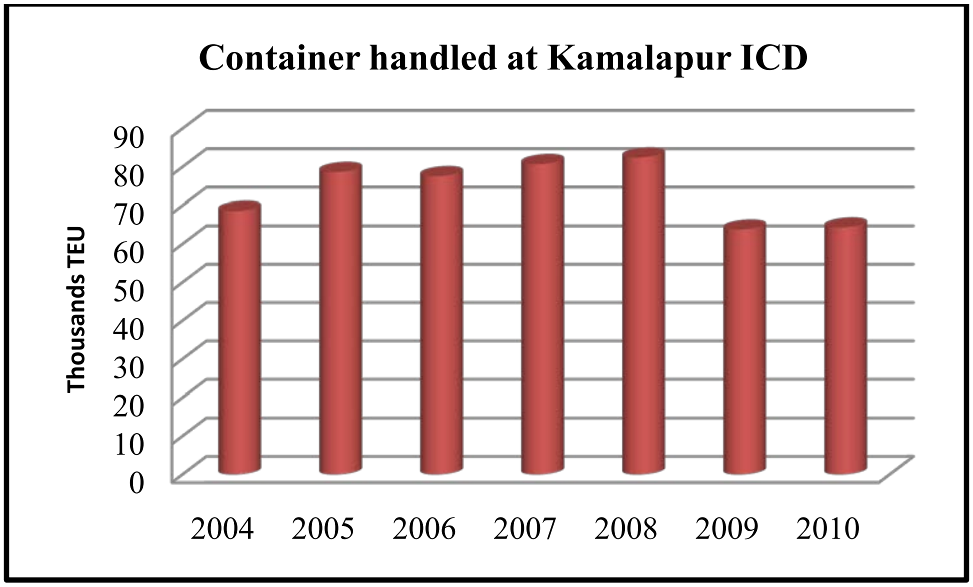
[11] Source: www.cikarangdryport.com

carriers, fork lift trucks and reach-stackers.

Figure 5.14 Block train and container yard in Kamalapur ICD, Dhaka

Initially it handled about 7% of country's total containers. Figure 5.15 shows the volume of container handled at Kamalapur ICD. It does not allow less than container loads (LCL) and has is no cargo storage facilities, so only full containers are handled. It handles both export and import, computerized customs clearance system is available. The office complex houses ICD office customs brokers, freight forwarders and banking facility. Figure 5.15 shows containers handled at Kamalapur ICD. The drop of container handled in 2009 and 2010 can be attributed to the global economic recession. In month of August 2011 it handled 5409 TEU. On 14th September 2011 there were 1358 containers in the ICD that is 33% of its capacity.

It was learned that as the ICD is generating operating profit and there was a competition between Bangladesh Railway (the owner) and Chittagong Port Authority (the operators) to operate the ICD even both are government undertakings. The operation agreement has recently been extended to another 10 years till 2021 to the Chittagong Port Authority. As the block train is operated by the Bangladesh Railway and ICD is operated by the Chittagong Port Authority there seems to be lack of coordination among the owner and operator.



Source: Kamalapur ICD 2011

Figure 5.15 Volume of container handled at Kamalapur ICD

A visit to the Kamalapur, ICD was undertaken on 14 September 2011 and met with operating officers, customs officers and observed its facility and operation. Lack of sufficient locomotives and wagons was mentioned as the constraint to increase the frequency of container block train from Chittagong port to the ICD. Further, it was mentioned that due to extensive built-up area nearby ICD it is difficult to expand its handling capacity. Therefore, the government is planning to develop another ICD in Dhirasram with handling capacity of 354,000 TEU. Improvement of ports, ICDs and container service can enhance the potential of Bangladesh to provide transit service to Bhutan and Nepal as well as West Bengal and North-East India. Bangladesh is giving high priority to improvement of Dhaka-Chittagong corridor.

Use of regular dedicated container block-trains in length of 320 km from ICD to Chittagong seaport take share of road transport and has reduced freight transport emissions in addition to reducing road congestion. However, there is need to increase these environmental benefits through procurement of locomotives and wagons and increasing frequency as well as efficiency of block train operation.

5.4 Key findings of the case studies

Table 5.2 summarizes some characteristics of dry ports related to their development and operation. All dry ports included in the case studies were evaluated in terms of modes served; environmental benefits/concerns; potential mode-shift opportunities; ownership; operational arrangements; government policies and incentives for the development of dry ports; and lessons learned from the development and operation of dry ports.

The case studies further supported the argument that the development of dry ports is at different stages of development in Asia. Therefore, there is a scope to further enhance its development and promote intermodal transport. All dry ports had railway connection and in most of the cases they

Table 5.2 Comparison of key features of selected dry ports

Key issues Dry ports	Modes served	Environmental benefits/concerns, potential of mode-shift	Ownerships	Operation	Government policies and incentives	Lessons learned from the development and operation of dry ports
Uiwang, South Korea	Rail, road	The use of railway to transport freight to/from ports to ICD contributes to a reduction in road congestion and vehicle emissions.	Public-private partnership	Private	Promotion of PPP projects through PIMAC.	Good example of PPP and role of PIMAC, connecting port and ICD with high-capacity railway can reduce road congestion.
Birgunj, Nepal	Rail, road	The modal shift to railway for transport between port and ICD, with collection and distribution of cargo by truck, contributes to emissions reduction.	Government	Private (leased)	Government investing in facility and has developed other dry ports as well.	Operation delayed due to delay in concluding rail service agreement with Indian Railways.
Lat Krabang, Thailand	Rail, road	Contribution to reduced road congestion and vehicle emission, but share of rail freight is decreasing due to vehicle queues, ICD congestion and limited railway capacity.	Public-private partnership	Private (Concession)	Concessions to private sector for development and operation. Considering capacity enhancement.	Congestion at ICD and limited capacity of railway connecting to port.
Alashankou, China	Rail, road	Long haul freight is mainly by rail. Development of dry ports, improvements of railway links and efficiency would contribute to environmental benefits.	Chinese Railway, CRCTC	Public-private CRCTC	Operation entrusted to CRCTC, a public-private venture.	Government policy in developing railways and dry ports and attract more share of freight to railways, capacity enhancement ongoing, starting double stack freight trains.
Tughlakabad, India	Rail, road	Transportation to/from ports is mainly by railway, with roads used for collection and distribution. Increasing trend of container handled at ICDs and transport to ports by railways shows overall positive environmental benefits.	CONCOR, Subsidiary of Indian Railway	Public undertaking	CONCOR investing in modernization of facilities and improving efficiency through improving fleet, dedicated platforms, use of ICT for container tracking.	Good ICD and railway network, dedicated freight corridors to enhance efficiency of operations.
Navoi, Uzbekistan	Air, road and rail	Mode shift possible but not currently, not enough freight volume for railway, reduction of air freight time.	Government	Private (management contractor)	Tax incentives and one stop service for licensing provided and Free Economic Zone established adjacent to the logistic centre.	Government policies and tax incentives were conducive to attract FDI. Limited volume of local freight.
Cikarang, Indonesia	Road and rail	Connected to Tanjung Priork Port by road and rail, now transportation is mainly by road.	Concession (Private sector)	Concession (Private sector)	Claims to be with state of art facilities-Single Window Clearance System, electronic security.	Reduce congestion at the port, relatively new dry port, so benefits are yet to be seen, need to connect to railways and start block train operation.
Kamalapur, Bangladesh	Road, rail	Connected to Chittagong port by railway, regular block train service running, distribution by road, limited handling capacity and constraint for expansion due to located in built-up area.	Bangladesh Railway	Chittagong Port Authority ((Government undertaking).	Due to limited capacity government planning development of other dry port at Dishasram, computerized customs processing and clearance facility available.	Limited capacity, lack of sufficient locomotives and wagons for freight, need to improve operational efficiency.

were connected to seaports by railways. The dry ports were at different distances from the seaport, Cikarang dry port and Lat Krabang ICD were close to the seaport, while the dry ports in China, Nepal and Uzbekistan were far away from the seaports. The Kamalapur ICD was at mid-range distance of 320 km from Chittagong seaport. These cases clearly illustrated their role in promoting mode shift and emission reduction, as 25% of the total throughput handled at Uiwang and Lat Krabang was carried by railways. Some dry ports had regular freight train service to/from seaports. The development of rail connected dry port in Nepal demonstrated reduction of large percentage of emissions. A further scope to improve efficiency of operation of railway system was indicate by the need to increase capacity of rail lines through double tracking, provision of efficient locomotives, provisions of sufficient wagons and improving load factors. The use of double stacking of containers in railway flat wagons in China demonstrated one of the measures to improve efficiency and load factor,

The partnerships and collaboration between public and private sector was evident from the cases and in some cases the need to enhance collaboration. In most cases, governments have involved in development where as either private sector or subsidiaries of governments were managing the operation. There was an interesting case of competition between two subsidiary government agencies to operate the Kamalapur ICD, as it was generating profit.

In addition to their function as logistics and distribution hubs, the role of dry ports as intermodal transfer points for mode shift as well as their emission reduction potential was also visible. New initiatives and policies would be required in Asia to further to promote the mode shift. The European Commission‘s Marco Polo project which aims to increase the share of rail freight in Europe (EC 2011) could serve as a good example for Asia. However, many Asian countries may not be in a position to introduce subsidies to railways yet to increase its mode share.

5.5 Requirement of a good dry port and policies

The review of the cases and literatures (ESCAP 2009a, United Nations 2007) show that there is a need of greater collaboration among the government agencies and stakeholders in planning, development and operation of dry ports. The following list though not comprehensive, can provide guidance on the requirement of a good dry port.

(i) Location at or near rail based intermodal terminals;
(ii) Access to seaports and air ports;
(iii) High quality and efficient transport system with connection to modes;
(iv) Railway connectivity with seaport with regular freight train service;
(v) Availability of sufficient cargo handling equipments, locomotives and wagons;
(vi) Continuous improvement of operation efficiency;
(vii) Use of advance information communication technology;
(viii) Meet need of the consumer capacity with full range of services;
(ix) Proximity to market and labour availability;
(x) Availability of large area for future phased expansion;
(xi) Located near free trade area or special economic zone;
(xii) Security of cargoes, container and customers, users;
(xiii) Proximity to manufacturing and production centres;

(xiv) Effective partnerships and cooperation between public and private companies;
(xv) Availability of office facilities with value added service; and
(xvi) Contribution to the development of regional and local economy.

The support and cooperation of government agencies is essential in planning, development and operation phase. During planning the government polices on licensing, allocation of land for the dry port as it needs larger area and financing relating to how to mobilize funding are essential. During operation provision and location of government service at the dry port are necessary. More importantly policy commitment of the government to streamlining customs clearance, reduction of documents to be handled in dealing with export and import, implementation single window system, eliminating double inspection of cargoes at the border as well and at the dry ports are some of the policy issues that are essential to attract freight to the dry port. In some instance, policies to encourage environmental friendly mode also is necessary for example through subsides In addition, sharing of experience gained in development and operation dry ports also becomes useful and can enhance capacity to planning, development and operation of dry ports.

5.6 Results and discussions

Case studies of development and operations of dry ports in Asia provided insight into the role of governments, markets, and the private sector in developing successful dry ports/ICDs. The case studies also served to emphasize various factors that have influenced the development and operation of dry ports and intermodal transport. Strong policy commitments by governments—aiming to bring together all facilities and services, including customs clearance, inspection, and consolidation, along with market-driven development—are some of the important factors that need to be considered. In addition, the dry ports/ICDs are being developed as growth centers near Free Trade Economic Zones (FTEZ) in order to attract investment and other services as in the case of Navoi Logistics Centre. Governments are able to initiate and promote such development, as shown by the case of South Korea and Uzbekistan. At times, governments need to "push" with new policies required to facilitate new developments and by liberalization and deregulation.

In addition to focusing upon infrastructural development, it is also necessary to consider operational issues in conjunction with infrastructure development. The discussion of road/rail service and international transit agreements takes considerable time, as shown by the case in Nepal. Here, dry port operation began two years after construction was completed because the conclusion of a rail service agreement with Indian Railway took longer time.

Railway connections to dry ports can reduce freight emissions through a modal shift that reduces the number of long-haul trucks plying on roads. The cases of Birgunj, Uiwang, Lat Krabang and Kamalapur demonstrate this potential as regular block train service is operated from these dry ports to respective ports. Moreover, the current congestion and pollution at Uiwang and Lat Krabang are isolated cases that are expected to be eased once the capacity of the ICDs is expanded and the share of rail freight is increased. Investment in railway infrastructure/dry ports can encourage modal shifts to greener modes of transport. In order to improve operational efficiency, the modernization of facilities and the use of cleaner and greener fuels are necessary.

In case of Kamalapur procurement of locomotives and wagons to increase frequency of block train service was necessary. The use of modern ICT technology is also important, as can be seen at the Tughlakabad ICD in India. In Cikarang relatively new dry port in Indonesia, apart from reducing congestion other environmental benefits are yet to be seen.

One policy issue that needs to be addressed is coordination among the various government agencies involved in the development of dry ports, including those responsible for licensing, investment, promotion of private-sector initiatives, etc. Both government and the private sector need to work together to develop intermodal transport in Asia that not only provides access to inland and landlocked areas but also promotes environmentally friendly freight transport. In case of Laos Nolitha (2011) argues that the development of dry port and logistics centers should be driven from real economic potential, implementation of facilitation measures and improvement of road infrastructure.

Developing dry ports in secure inland areas away from vulnerable coastal area can support the adaptation initiative and contributes towards development of sustainable intermodal transport system and enhance its sustainability to withstand potential impacts of climate change.

5.7 Chapter summary

This chapter provided an overview of development of dry port in Asia through description of case studies. It highlighted importance of policy initiative of the government as well as the need to have partnerships with private sector for its development and operation.

The chapter also illustrated many factors and issues that need to be considered while planning, developing and operating dry ports. It also provided some empirical evidence on the environmental benefits that dry ports and its role in supporting mitigation through promotion of modal shift. The cases of Lat Krabang, Uiwang and Birgunj illustrated this fact. The list of requirement of a good dry port and policies suggested in this chapter can provide some guidance and would be useful in development and operation. The location analysis of dry ports is another important issue as it involves different interest of stakeholders, which is discussed and analyzed in next chapter.

CHAPTER 6

LOCATION ANALYSIS OF DRY PORTS

6.1 Introduction

This chapter presents the analysis of primary data collected for analysis of dry port locations. The results of survey of policy makers indicated that there is a further need to provide information to enhance awareness and understanding of transport problems. Presenting the results of module 2 to the decision makers would assist and support in their decision making. Initially, the detail of AHP survey is provided and the potential locations of dry ports in Laos are analyzed using module 2 that incorporates AHP and goal programming.

6.2 Survey for analysis of dry port locations in Laos

Inland dry ports are important nodes of intermodal transport. Their development in inland areas including land locked countries would facilitate modal shift and help reduce emissions from transport. There are many criteria that need to be considered for selecting/prioritizing location for dry ports. A survey of policy makers, freight forwarders and multimodal transport operators for the analysis of dry port locations in Laos was undertaken. The data collection process included interview survey, visits to the potential four dry ports location, and meetings with stakeholders in Savannakhet and Vientiane. This section outlines details of primary data collection for AHP and GP analysis for location priority of dry ports in Laos.

6.2.1 Selection of evaluation criteria and sub-criteria

The first task is to develop AHP model for multicriteria decision analysis (MCDA) considering various criteria and sub-criteria that would be important in deciding the potential location of dry ports. Considering the situation in Laos, and after extensive review of criteria and elements considered by earlier studies, the criteria and sub criteria shown in Table 6.1 were selected for the analysis of dry ports location. Prior to finalizing, these were sent to transport policy makers in Laos and transportation professionals for their feedback. Five evaluation criteria and 12 sub-criteria were chosen as suggested by literature to limit number of criteria to 6. This reduces the number of questions for pair-wise comparisons, increases chance of receiving more responses and avoids complex calculations. The criteria and sub-criteria are considered to be independent of each other.

Table 6.1 Selected evaluation criteria and sub-criteria for AHP analysis

Criteria	Sub-criteria
Development and operation costs (C1)	Land acquisition costs (C11)
	Construction costs (C12)
	Transportation costs (C13)
Transportation time (C2)	Total transport time from seaport (C21)
Intermodal transport connectivity (C3)	Highways (C31)
	Railways (C32)
	Inland waterways (C33)
	Seaports (C34)
Environmental impacts (C4)	Impacts from construction (C41)
	Impacts from transport operation (C42)
Regional economic development (C5)	Proximity to market, production centres and consumers (C51)
	Government polices to develop special economic zone or free trade area nearby (C52)
	Freight demand (C53)

The four selected alternative locations of dry ports are based on that proposed the Laos Logistics Development Plan. These locations are close to border with Thailand and could facilitate international trade as Laos trade with Thailand accounts for more than 80% of international trade (ADB 2008). Figure 6.1 and Table 6.2 show four locations alternative dry ports.

Table 6.2 Alternative dry port locations

S. No.	Location
Alt 1	Thanalaeng
Alt 2	Thakhek
Alt 3	Savannakhet
Alt 4	Phakse

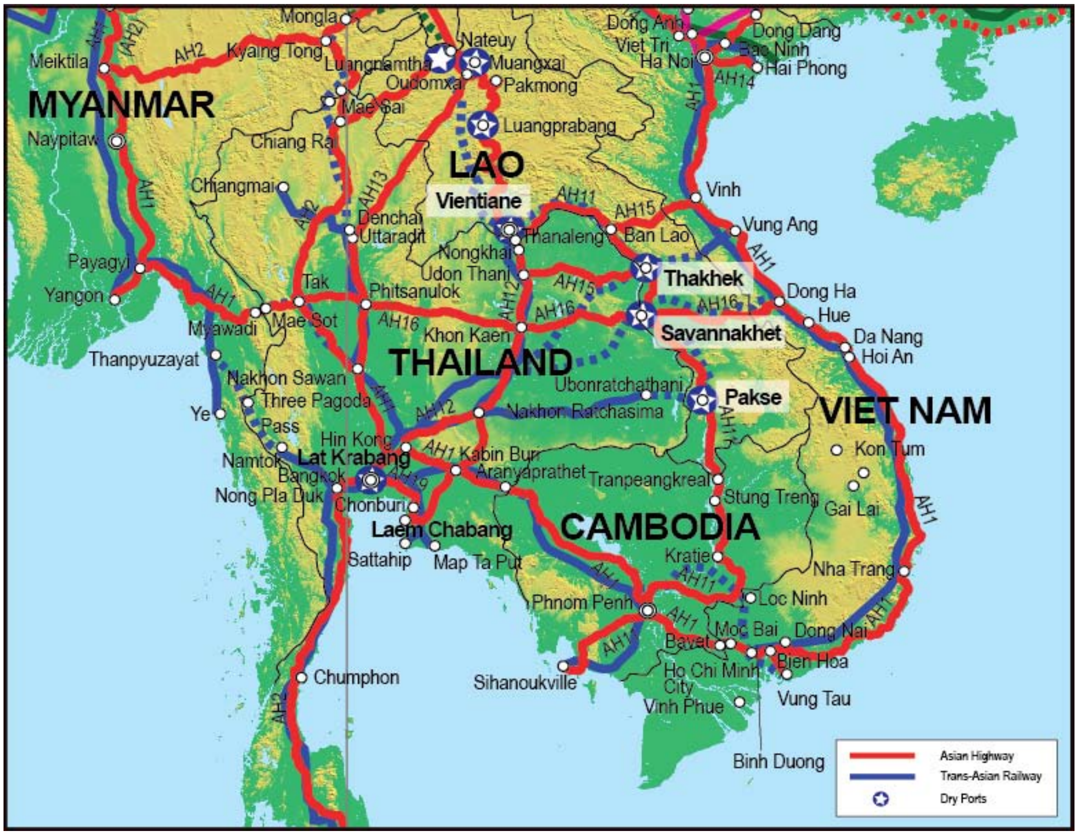


Figure 6.1 Location of dry ports

6.2.2 Questionnaire development

Questionnaire survey for pair-wise comparison of criteria, sub-criteria and alternative locations was developed and refined based on the feedback received from researchers, government officials and transport professionals. Even though the evaluation criteria were limited to five main criteria and 12 sub-criteria, the total number of questions included in the questionnaire were 101 for pair-wise comparison in addition to seven questions on general information of the respondents. The respondents were asked to make pair-wise comparison and rate/judge their preference in Saaty's 1 to 9 scale. The questionnaire included four sections: section I on general information of the respondents; section II on evaluation of main criteria; section III on evaluation of sub-criteria; and section IV on preference of alternative dry ports locations with respect to a criterion/sub-criterion. Figure 6.2 shows a sample of question for comparing two criteria. The full questionnaire is included as Appendix-III.

Please indicate in 1- 9 point scale while making **pair wise comparison** of two criteria/sub-criteria in a row. Please mark only **one box** in a row.

S. No	Criteria	**Extremely important**		**Very important**		**Important**		**Slightly important**		**Equally Important**		**Slightly important**		**Important**		**Very important**		**Extremely Important**	Criteria
1	**Development & transport costs**	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Time**

Figure 6.2 Format of pair-wise comparaison questionnaire

6.2.3 Selection of respondents and the survey

Contact was maintained with transport and logistics related government officials, Laos International Freight Forwarders' Association (LIFFA) and Lao National Chambers of Commerce and Industry (LNCCI) to develop a long list of potential respondents. From the long list 50 people were selected for the survey that included 23 government officials, all (22) members of LIFFA and 5 members of LNCCI.

Prior to the visit to Laos for survey, the questionnaire was sent to all 50 potential respondents. On site data collection was done during 6-12 July 2011. The survey of the government policy makers was conducted during a subregional meeting on dry ports held in Vientiane on 7 and 8 July 2011. They were briefed on the objective and how to complete the response. The interview survey of freight forwarders was done during 9-12 July 2011.

Additional survey inputs were also requested during meeting at the Ministry of Public Works and Transport on 11 July 2011. Similar approach was taken after the meeting with LIFFA and LNCCI some questionnaires were left and collected on next day. In some cases, the replies were received by email after returning to Bangkok. Repeated follow-ups, with email reminders and telephone calls were made but without much success, to receive more response to survey.

Total 24 responses were received with an overall response rate of 48%. The response of private sector was 44.4% (12 response from 27 requests) compared with government policy makers 52% (12 response from 23 requests). The total number of responses received can be considered quite satisfactory as all most all sectors of policy makers related to the transport and logistics and 8 freight forwarders (36.4% of LIFFA members) provided feedback. Two questionnaires received were incomplete and were discarded. Most of the responses received were consistent. Figure 6.3 shows gender and distribution of the respondents.

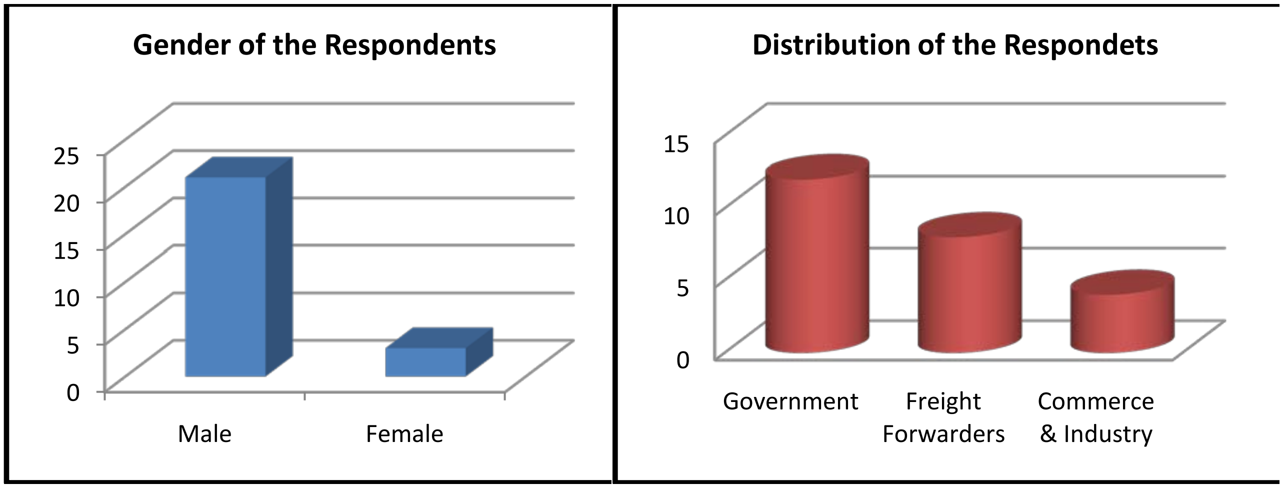


Figure 6.3 Gender and distribution of the respondents of AHP survey.

The opinion of the respondents received from the survey is used to evaluate location of dry ports by AHP. The outputs of AHP were utilized as input for the GP model for further analysis of dry port locations.

6.2.4 Field visit to potential dry port locations

The data collection also involved field visits to all four alternative locations, Thanalaeng, Thakhek, Savannakhet, and Phakse, during 9-12 July 2011. It also involved meetings and discussions with freight forwarders, private sector representatives, and government officials at Vientiane and Savannakhet. The discussion during these meetings focused to receive feedback and perception on the importance of development of dry ports, modal shift, and development of rail freight transport. The following provides a brief description of four dry port locations.

(i) Thanalaeng

An area near Thanalaeng railway station is selected for dry port/logistic park. Currently only passenger train is in operation. It is expected to grow and serve as transshipment and distribution centre for cargo coming and going the north using National Road NR-13N. Figure 6.4 shows existing railway station and road border crossing from the Friendship Bridge. The railway needs to be extended to the logistic park including siding to the railway track.

Figure 6.4 Friendship bridge border check posts and Thanalaeng railway station

(ii) Thakhek

Figure 6.5 shows the 3rd Mekong Bridge. During the visit, this was under construction to connect Thakhek with Nakhon Phanom. The existing ferry upstream of Thakhek was used to cross the Mekong River. The bridge has opened as planned on 11 November 2011. The bridge now provides short transport connection along the Asian Highway road 15 to Vietnam through border Ban Lao.

Figure 6.5 New 3rd Mekong Bridge at Thakhek and existing ferry upstream

(iii) Savannakhet

Savannakhet is being developed as international logistics hub. The government is also supporting its development through free economic zone, the Savan-Seno Free Economic Zone (SSFEZ). Figure 6.6 shows the 2nd Mekong River Bridge that facilitates international and transit traffic along the Mekong-East West Corridor. The site for the logistic park is about 24 km from the bridge and Savannakhet city.

Figure 6.6 Border check post at Savannakhet and container truck

(iv) Phakse

The logistic park at Phakse function is seen as more of supporting local and bilateral trade with Thailand rather than international trade. Laos's international trade with Cambodia is very negligible despite its proximity with Champasak province. The site selected for the logistic center is near the border crossing point at Vang Tao. It is near to the new planned custom office. Figure 6.7 shows the border crossing point of Vang Tao and Chong Mek.

Figure 6.7 Border crossing point Vang Tao-Chong Mek and truck at border

Thailand is planning to develop dual track system railway from Ubon Ratchathani and Laos border. The Office of Transport and Traffic Policy and Planning (OTP) is undertaking feasibility study and plans to spend 85 million baht for (Bangkok Post 2011) covering Ubon Ratchthani and Chong Mek. The last train stop is Warin Chamrap and 80 km extension to Chong Mek (border with Laos) would cost about 10 billion baht. The dual track system would make logistics more efficient as the value of trade between Thailand and Laos is 5.5 billion/year.

6.2.5 Limitation of the survey

During the survey it was felt that the questionnaire was too long as it contained 101 questions and took around 20-30 minutes to complete. As a result, some of the potential respondents promised to provide feedback but never did. However, due to large numbers of questions, some questions were left unanswered due to possible “reply fatigues.”

6.3 Location analysis of dry ports in Laos

The analysis is done using AHP which can consider both quantitative and qualitative criteria and derive relative weights and prioritize alternate locations based on selected criteria and sub-criteria. It may not be always possible to measure and present these factors –as numerical values. Rather these factors are expressed as value judgment, preferred options based on criteria. Three AHP models are developed and analyzed based on the feedback received on evaluation criteria and sub-criteria and alternatives. The local and global weights are derived, synthesis was done to arrive at final priority, and consistency check was done.

6.3.1 Analytic hierarchy process model

The location problem is decomposed into four levels of hierarchy consisting of (i) one goal; (ii) five criteria; (iii) 12 sub-criteria; and (iv) four alternatives. The four alternatives selected represent actual location of dry ports in Laos, they are namely: Thanalaeng; Thakhek; Savannakhet; and Phakse (see Figure 6.1). These are reflected in the government’s five-year logistic plan (MPI 2011) and were proposed for development during a regional meeting on dry ports (ESCAP 2010c). These locations were also studied in the Laos Logistics Master Plan Study (JICA 2011). This decomposition of decision problem makes it possible to judge the importance of the elements in a given level with respect to other elements in the same level.

6.3.2 Pair-wise comparison and derivation of weights

The location analysis is based on the 24 feedback received from targeted 50 requests with an overall response rate of 48%. The total number of feedback received from freight forwarders was 8 which represented 36% of total LIFFA members as total registered members of LIFFA are 22 in Laos. 4 responses (80% response rate) were received from chamber of commerce and industries. It also includes feedback from almost all sectors of officials that are related to logistics development representing public works and transport, department of roads, department of transport, customs, railway, national transport facilitation committee, legal affairs, and officials of special economic zones. Table 6.3 shows the summary of survey response.

The individual survey responses were tabulated and aggregated separately in two groups and analyzed formulating government decision makers (GODM) and private sector freight forwarder (PSFF) models. The third model combines all feedback received from the government decision makers and private sector freight forwarders, and is referred as the combined model (COMB). Thus three types of AHP model are developed. This would be useful in comparing the preference of the policy makers and private sector freight forwarders.

Table 6.3 Details of survey response

Type of respondents	No. of requests	No of replies	% feedback received	Valid response	% of valid response	Model
Government Decision makers	23	12	52%	12	54.6%	**GODM**
Private sector	27	12	44.4%	10	45.4%	**PSFF**
Freight forwarders	*22*	*8*	*36.4%*	*8*	*36.3*	
Commerce and industry	*5*	*4*	*80%*	*2*	*9.1%*	
Total	**50**	**24**	**48%**	**22**	**92%**	**COMB**

6.3.2.1 Derivation of weights of main criteria

The respondents were asked to indicate their value judgment/preference in a 1 to 9 point scale while making pair wise comparison. A judgmental matrix is developed based on pair-wise comparison of priorities of criteria. The judgmental matrix of the main criteria for the Government Decision Makers' Model (GODM) is shown in Table 6.4. In the judgmental matrix, the values in matrix are not whole numbers, as geometric means method was used to aggregate the responses so as to reflect views of all respondents. Using normalization and eigenvector method, the weights of the five criteria were calculated. The weights were calculated using the AHP analysis software. It shows the high importance assigned to the regional economic development (C5), transportation cost (C1) and intermodal transport connectivity (C3) by the policy makers. The consistency ratio was 0.02.

Table 6.4 Judgmental matrix of evaluation criteria (GODM)

	C1	**C2**	**C3**	**C4**	**C5**	**Weights**
C1	1	2.4	1/ 1.2	1.4	1/ 1.2	0.238
C2	1/2.4	1	1.2	1/1.5	1/1.9	0.124
C3	1.0	1/1.4	1	1.5	1.1	0.230
C4	1/1.4	1.5	1/ 1.5	1	1/1.4	0.168
C5	1.2	1.9	1/ 1.1	1.4	1	0.239

Similarly, Table 6.5 shows the judgmental matrix and resulting weights of main criteria of private sector freight forwarders (PSFF) model. The overall consistency ratio was 0.05. Interestingly, the freight forwarders have assigned high priority to the environmental impacts (C4) followed by regional economic development (C5).

Table 6.5 Comparison matrix of PSFF model

	C1	C2	C3	C4	C5	Weights
C1	1	2.5	1/ 1.5	1/2.7	1/ 3.6	0.141
C2	1/2.5	1	1.0	1/1.6	1/1.6	0.130
C3	1.5	1.0	1	1/2.6	1/2.1	0.137
C4	2.7	1.6	2.6	1	1.4	0.309
C5	3.6	1.6	2.1	1/1.4	1	0.283

Table 6.6 shows the comparison matrix and derived weights of COMB model which incorporates the feedback of the government policy makers and private sector freight forwarders. The result shows the high importance given by the respondents to the regional economic development (C5) and environmental impacts (C4) criteria for location selection decisions. The transportation time was considered as the least important criteria by the respondents.

Table 6.6 Comparison matrix of COMB model

	C1	C2	C3	C4	C5	Weights
C1	1	2.4	1/ 1.2	1/1.1	1/ 1.7	0.202
C2	1/2.4	1	1/1.2	1/1.5	1/1.7	0.133
C3	1.2	1.2	1	1.0	1/1.2	0.201
C4	1.1	1.6	1.0	1	1/1.1	0.209
C5	1.7	1.7	1.2	1.1	1	0.255

Table 6.7 summarizes the derived weights of five evaluation criteria for three models. The consistency ratio (CR) is also shown in the Table which in all case is less than 0.1 indicating consistency of the pair-wise comparison and weight derivation.

Table 6.7 Derived weights of evaluation criteria

Criteria	GODM (C.R=0.02)	PSFF (C.R=0.05)	COMB (C.R.=0.02)
Development and operation costs (C1)	0.238	0.141	0.202
Transportation time (C2)	0.124	0.130	0.133
Intermodal transport connectivity (C3)	0.230	0.137	0.201
Environmental impacts (C4)	0.168	0.309	0.209
Regional economic development (C5)	0.239	0.283	0.255

The above results show that the government decision makers assign high priority to the regional economic development, followed by the development and operation cost and intermodal transport connectivity. While the environmental impacts received second lowest weight indicating low importance and time for the government policy makers. Interestingly, private sector and freight forwarders assign high priority to the environmental impacts followed by the regional economic development. Based on the analysis, the private sector seems to be more responsible to environmental issues as they can visualize the difference they can make. It also could be partly from their corporate social responsibility. Ideally, government decision makers should also be aware of this. It could be that they could not foresee impacts of their policies. This is in line with outcome of adaption survey that have shown the need to create more awareness of government policy makers on environmental and climate change issues

6.3.2.2 Weights of sub-criteria

The respondents were asked to indicate his value judgment/preference in a 1 to 9 point scale while making pair wise comparison of sub-criteria within one criterion. A judgmental matrix is developed based on pair-wise comparison. Tabulating and aggregating the individual judgments and feedback received from the survey, weights of sub-criteria are derived. There would be four matrices for each model corresponding to each criterion having sub-criteria. The transportation time does not have sub-criteria, so there would be no matrix for time. So evaluating 12 matrices gives the local priority weight of the sub-criteria. Table 6.8 shows judgmental evaluation matrices comparing the importance of sub-criteria of government decision makers model (GODM).

Table 6.8 Evaluation matrices of sub-criteria for GODM model

Costs

	C11	C12	C13	Weights
C11	1	1/1.6	1/1.1	0.274
C12	1.6	1	1/1.1	0.352
C13	1.1	1.1	1	0.374

Transport connectivity

	C31	C32	C33	C34	Weights
C31	1	1.3	3.1	4.3	0.423
C32	1/1.3	1	2.1	3.3	0.338
C33	1/3.1	1/2.1	1	2.1	0.149
C34	1/4.3	1/3.3	1/2.1	1	0.090

Environmental impacts

	C41	C42	Weights
C41	1	1	0.5
C42	1	1	0.5

Regional development

	C51	C52	C53	Weights
C51	1	1.3	1.9	0.425
C52	1/1.3	1	2.4	0.386
C53	1/1.9	1/2.4	1	0.190

In similar manner, Table 6.9 shows the matrices and weights derived from various sub-criteria of PSFF model.

Table 6.9 Evaluation matrices of sub-criteria for PSFF model

Cost

	C11	C12	C13	Weights
C11	1	1.7	1/2.3	0.266
C12	1/1.7	1	1/3.1	0.169
C13	2.3	3.1	1	0.566

Transport Connectivity

	C31	C32	C33	C34	Weights
C31	1	1.1	1/1.3	2.3	0.280
C32	1/1.1	1	3.0	1.8	0.359
C33	1.3	1/3.0	1	1.3	0.211
C34	1/2.3	1/1.8	1/1.3	1	0.150

Environmental impacts

	C41	C42	Weights
C41	1	1.4	0.583
C42	1/1.4	1	0.417

Regional development

	C51	C52	C53	Weights
C51	1	1/2.0	1/1.4	0.221
C52	2.0	1	2.2	0.511
C53	1.4	1/2.2	1	0.268

In similar manner, Table 6.10 shows the matrices and weights derived from various sub-criteria of COMB model that incorporates feedback of government decision makers and private sector freight forwarders.

Table 6.10 Evaluation matrices of sub-criteria for COMB model

Cost

	C11	C12	C13	Weights
C11	1	1.1	1/1.8	0.276
C12	1/1.1	1	1/1.4	0.282
C13	1.8	1.4	1	0.442

Transport Connectivity

	C31	C32	C33	C34	Weights
C31	1	1.2	1.8	3.4	0.365
C32	1/1.2	1	2.8	2.6	0.352
C33	1/1.8	1/2.8	1	1.7	0.170
C34	1/3.4	1/2.6		1	0.113

Environmental impacts

	C41	C42	Weights
C41	1	1.1	0.524
C42	1/1.1	1	0.476

Regional development

	C51	C52	C53	Weights
C51	1	1/1.1	1.3	0.340
C52	1.1	1	2.3	0.438
C53	1/1.3	1/2.3	1	0.222

Table 6.11 shows the summary of evaluation above matrices with derived local weight of the evaluation sub-criteria and consistency ratio calculated using AHP analysis software. By multiplying this local weight with weight of corresponding criteria–global weight of each criterion is derived later.

Table 6.11 Derived weights of sub-criteria

		Local priority weights		
Criteria	Sub-criteria	GODM	PSFF	COMB
Development and operation costs (C1)	Land acquisition costs (C11) Construction costs (C12) Transportation costs (C13)	0.274 0.352 0.374 (C.R=0.02)	0.266 0.169 0.566 (C.R=0.01)	0.276 0.282 0.442 (C.R=0.01)
Time (C2)	Total transport time from seaport (C21)	1	1	1
Intermodal transport connectivity (C3)	Highways (C31) Railways (C32) Inland waterways (C33) Seaports (C34)	0.423 0.338 0.149 0.090 (C.R=0.01)	0.280 0.359 0.211 0.150 (C.R=0.08)	0.365 0.352 0.170 0.113 (C.R=0.02)
Environmental impacts (C4)	Impacts from construction (C41) Impacts from transport operation (C42)	0.50 0.50 (C.R=0.0)	0.583 0.417 (C.R=0.0)	0.524 0.476 (C.R=0.0)
Regional economic development (C5)	Proximity to market, production centers and consumers (C51) Government polices to develop special economic zone or free trade area nearby (C52) Freight demand (C53)	0.425 0.386 0.190	0.221 0.511 0.268	0.340 0.438 0.222

		(C.R=0.03)	(C.R=0.02)	(C.R=0.02)

6.3.2.3 Location comparison with sub-criteria

The respondents were asked to indicate their value judgment/preference in a 1 to 9 point scale while making pair wise comparison of alternative dry ports with respect to each evaluation sub-criterion. A judgmental matrix corresponding to each sub-criterion is developed based on pair-wise comparison of the locations. There are 13 matrices for each model corresponding to each sub-criterion. The relative weights of the dry ports location corresponding to a criterion being considered is determined and is used for overall synthesis later. The analysis is done with AHP software after entering data to the corresponding evaluation matrix. Table 6.12 shows evaluation matrices for comparison of alternatives with respect to sub-criteria for the government decision makers' model (GODM Model).

Table 6.12 Evaluation matrices for alternatives with sub-criteria (GODM)

	Alt 1	Alt 2	Alt 3	Alt 4	Weights
Alt 1	1	1/1.3	1/1.5	1/1.3	0.194
Alt 2	1/3	1	1.2	1.3	0.292
Alt 3	1.5	1/1.2	1	1/1.9	0.223
Alt 4	1.3	1/1.3	1.9	1	0.291

Land acquisition cost (C11)

	Alt 1	Alt 2	Alt 3	Alt 4	Weights
Alt 1	1	1.1	1/1.2	1	0.243
Alt 2	1/1.1	1	1/1.2	1/1.5	0.209
Alt 3	1.2	1.2	1	1/1.2	0.260
Alt 4	1	1.5	1.2	1	0.288

Construction costs (C12)

	Alt 1	Alt 2	Alt 3	Alt 4	Weights
Alt 1	1	1.8	1.6	1.8	0.363
Alt 2	1/1.8	1	1/1.6	1/1.8	0.159
Alt 3	1/1.6	1.6	1	1/1.2	0.227
Alt 4	1/1.8	1.8	1.2	1	0.251

Transportation costs (C13)

	Alt 1	Alt 2	Alt 3	Alt 4	Weights
Alt 1	1	1/1.3	1/1.7	1/1.1	0.196
Alt 2	1.3	1	1/1.4	1/1.1	0.236
Alt 3	1.7	1.4	1	1.6	0.241
Alt 4	1.1	1.1	1/1.6	1	0.228

Transportation time (C21)

	Alt 1	Alt 2	Alt 3	Alt 4	Weights
Alt 1	1	1.6	1.1	1.5	0.312
Alt 2	1/1.6	1	1/1,6	1/1.2	0.185
Alt 3	1/1.1	1.6	1	1.1	0.276
Alt 4	1/1.5	1.2	1/1.1	1	0.227

Highway connectivity (C31)

	Alt 1	Alt 2	Alt 3	Alt 4	Weights
Alt 1	1	3.3	3.6	3.6	0.533
Alt 2	1/3.3	1	1.7	1.4	0.193
Alt 3	1/3.6	1/1.7	1	1.4	0.145
Alt 4	1/3.6	1/1.4	1/1.4	1	0.129

Railway connectivity (C32)

	Alt 1	Alt 2	Alt 3	Alt 4	Weights
Alt 1	1	1.4	1.1	1.4	0.301
Alt 2	1/1.4	1	1.3	1.6	0.244
Alt 3	1/1.1	1/1.3	1	1	0.228
Alt 4	1/1.4	1/1.6	1	1	0.227

Inland waterway connectivity (C33)

	Alt 1	Alt 2	Alt 3	Alt 4	Weights
Alt 1	1	1/1.5	1/2.4	1/1.2	0.164
Alt 2	1.5	1	1/1.6	1.4	0.253
Alt 3	2.4	1.6	1	1.9	0.389
Alt 4	1.2	1/1.4	1/1.9	1	0.194

Seaports connectivity (C34)

	Alt 1	Alt 2	Alt 3	Alt 4	Weights
Alt 1	1	1.4	1.4	1.4	0.314
Alt 2	1/1.4	1	1.7	1/1.4	0.238
Alt 3	1/1.4	1/1.7	1	1/1.3	0.186
Alt 4	1/1.4	1.4	1.3	1	0.262

Environmental impacts from construction (C41)

	Alt 1	Alt 2	Alt 3	Alt 4	Weights
Alt 1	1	1.3	1.2	1.4	0.301
Alt 2	1/1.3	1	1.5	1/1.3	0.240
Alt 3	1/1.2	1/1.5	1	1/1.3	0.200
Alt 4	1/1.4	1.3	1.3	1	0.259

Environmental impacts from operation (C42)

	Alt 1	Alt 2	Alt 3	Alt 4	Weights
Alt 1	1	1.7	2.3	1.8	0.389
Alt 2	1/1.7	1	1/2.1	1/1.3	0.163
Alt 3	1/2.3	2.1	1	1.1	0.239
Alt 4	1/1.8	1.3	1/1.1	1	0.209

Proximity to markets (C51)

	Alt 1	Alt 2	Alt 3	Alt 4	Weights
Alt 1	1	1/1.1	3.0	1.3	0.352
Alt 2	1.1	1	1/1.8	1/1.3	0.202
Alt 3	1/3	1.8	1	1.7	0.245
Alt 4	1/1.3	1.3	1/1.7	1	0.201

Government's SEZ/FTA Policies (C52)

	Alt 1	Alt 2	Alt 3	Alt 4	Weights
Alt 1	1	2.3	1.9	1.7	0.388
Alt 2	½.3	1	1/1.8	1/1.8	0.142
Alt 3	1/1.9	1.8	1	1.3	0.247
Alt 4	1/1.7	1.8	1/1.3	1	0.223

Freight Demand (C53)

Table 6.13 shows the evaluation matrices of alternative location with respect to sub-criterion for PSFF model.

Table 6.13 Evaluation matrices of alternatives with sub-criteria (PSFF)

	Alt 1	Alt 2	Alt 3	Alt 4	Weights
Alt 1	1	1/1.3	1/2.3	1/3.5	0.127
Alt 2	1.3	1	1/1.2	1/1.1	0.233
Alt 3	2.3	1.2	1	1/2.3	0.239
Alt 4	3.5	1.1	2.3	1	0.401

Land acquisition cost (C11)

	Alt 1	Alt 2	Alt 3	Alt 4	Weights
Alt 1	1	1/1.2	1/1.4	1	0.219
Alt 2	1.2	1	1/1.2	1/1.5	0.224
Alt 3	1.4	1.2	1	1/1.2	0.268
Alt 4	1	1.5	1.2	1	0.289

Construction costs (C12)

	Alt 1	Alt 2	Alt 3	Alt 4	Weights
Alt 1	1	2.1	1.6	2.6	0.397
Alt 2	1/2.1	1	1/2.1	1.2	0.168
Alt 3	1/1.6	2.1	1	1.6	0.280
Alt 4	1/2.6	1/1.2	1/1.6	1	0.155

Transportation costs (C13)

	Alt 1	Alt 2	Alt 3	Alt 4	Weights
Alt 1	1	1.3	1.4	1.7	0.325
Alt 2	1/1.3	1	1/1.7	1	0.201
Alt 3	1/1.4	1.7	1	1.4	0.279
Alt 4	1/1.7	1	1/1.4	1	0.195

Transportation time (C21)

	Alt 1	Alt 2	Alt 3	Alt 4	Weights
Alt 1	1	1/1.7	1/1.6	1/1.2	0.180
Alt 2	1.7	1	1.2	1.3	0.310
Alt 3	1.6	1/1.2	1	1.8	0.304
Alt 4	1.2	1/1.3	1/1.8	1	0.206

Highway connectivity (C31)

	Alt 1	Alt 2	Alt 3	Alt 4	Weights
Alt 1	1	1.4	2.7	2.5	0.414
Alt 2	1/1.4	1	1/1.2	1/1.1	0.203
Alt 3	1/2.7	1.2	1	1.6	0.215
Alt 4	1/2.5	1.1	1/1.6	1	0.169

Railway connectivity (C32)

	Alt 1	Alt 2	Alt 3	Alt 4	Weights
Alt 1	1	1/1.5	1.5	1.3	0.268
Alt 2	1.5	1	1/1.1	1/1.5	0.249
Alt 3	1/1.5	1.1	1	1/1.1	0.220
Alt 4	1/1.3	1.5	1.1	1	0.263

Inland waterway connectivity (C33)

	Alt 1	Alt 2	Alt 3	Alt 4	Weights
Alt 1	1	1/1.3	1/1.5	1.2	0.204
Alt 2	1.3	1	1/2.7	2.0	0.231
Alt 3	1.5	2.7	1	2.5	0.419
Alt 4	1/1.2	1/2	1/2.5	1	0.146

Seaports connectivity (C34)

	Alt 1	Alt 2	Alt 3	Alt 4	Weights
Alt 1	1	1.4	1.5	1/1.2	0.282
Alt 2	1/1.4	1	1.4	1.3	0.264
Alt 3	1/1.5	1/1.4	1	1/1.9	0.171
Alt 4	1.2	1/1.3	1.9	1	0.283

Environmental impacts from construction (C41)

	Alt 1	Alt 2	Alt 3	Alt 4	Weights
Alt 1	1	2	1.9	2.3	0.406
Alt 2	1/2	1	1.3	1/1.3	0.196
Alt 3	1/1.9	1/1.3	1	1/1.8	0.162
Alt 4	1/2.3	1.3	1.8	1	0.236

Environmental impacts from operation (C42)

	Alt 1	Alt 2	Alt 3	Alt 4	Weights
Alt 1	1	3.3	1.4	2.7	0.415
Alt 2	1/3.3	1	1/2.8	1/1.2	0.121
Alt 3	1/1.4	2.8	1	2.0	0.312
Alt 4	½.7	1.2	1/2	1	0.152

Proximity to markets (C51)

	Alt 1	Alt 2	Alt 3	Alt 4	Weights
Alt 1	1	1/2.3	1/4.2	1/2.3	0.101
Alt 2	2.3	1	1/1.6	1/1.4	0.223
Alt 3	4.2	1.6	1	2.2	0.433
Alt 4	2.3	1.4	1/2.2	1	0.243

Government's SEZ/FTA Policies (C52)

	Alt 1	Alt 2	Alt 3	Alt 4	Weights
Alt 1	1	2.7	1	2.2	0.350
Alt 2	1/2.7	1	1/2.2	1/1.4	0.133
Alt 3	1	2.2	1	2.9	0.361
Alt 4	1/2.2	1.4	1/2.9	1	0.156

Freight Demand (C53)

Table 6.14 shows evaluation matrices of alternative locations with respect to each evaluation sub-criterion for the combined model (COMB).

Table 6.14 Evaluation matrices of alternatives with sub-criteria (COMB)

	Alt 1	Alt 2	Alt 3	Alt 4	Weights
Alt 1	1	1/1.3	1/1.7	1/1.8	0.171
Alt 2	1.3	1	1.1	1/1.2	0.251
Alt 3	1.7	1/1.1	1	1/2	0.228
Alt 4	1.8	1.2	2	1	0.350

Land acquisition cost (C11)

	Alt 1	Alt 2	Alt 3	Alt 4	Weights
Alt 1	1	1	1/1.3	1	0.233
Alt 2	1	1	1/1.3	1/1.2	0.222
Alt 3	1.3	1.3	1	1/1.1	0.278
Alt 4	1	1.2	1.1	1	0.267

Construction costs (C12)

	Alt 1	Alt 2	Alt 3	Alt 4	Weights
Alt 1	1	1.9	1.6	2.1	0.376
Alt 2	1/1.9	1	1/1.8	1.3	0.189
Alt 3	1/1.6	1.8	1	1.1	0.254
Alt 4	1/2.1	1/1.3	1/1.1	1	0.281

Transportation costs (C13)

	Alt 1	Alt 2	Alt 3	Alt 4	Weights
Alt 1	1	1/1.1	1/1.2	1.1	0.237
Alt 2	1.1	1	1/1.5	1/1.1	0.224
Alt 3	1.2	1.5	1	1.5	0.317
Alt 4	1/1.1	1.1	1/1.5	1	0.222

Transportation time (C21)

	Alt 1	Alt 2	Alt 3	Alt 4	Weights

	Alt 1	Alt 2	Alt 3	Alt 4	Weights

					Weights
Alt 1	1	1.1	1/1.1	1.2	0.260
Alt 2	1/1.1	1	1/1.2	1	0.232
Alt 3	1.1	1.2	1	1.3	0.285
Alt 4	1/1.2	1	1/1.3	1	0.223

Highway connectivity (C31)

					Weights
Alt 1	1	2.4	3.2	3.1	0.486
Alt 2	1/2.4	1	1.3	1.2	0.198
Alt 3	1/3.2	1/1.3	1	1.5	0.172
Alt 4	1/3.1	1/1.2	1/1.5	1	0.144

Railway connectivity (C32)

	Alt 1	Alt 2	Alt 3	Alt 4	Weights
Alt 1	1	1.1	1.2	1.3	0.285
Alt 2	1/1.1	1	1.1	1/1.2	0.238
Alt 3	1/1.2	1/1.1	1	1	0.232
Alt 4	1/1.3	1.2	1	1	0.245

Inland waterway connectivity (C33)

	Alt 1	Alt 2	Alt 3	Alt 4	Weights
Alt 1	1	1/1.4	1/2.4	1/1.1	0.168
Alt 2	1.4	1	1/1.9	1.6	0.244
Alt 3	2.4	1.9	1	2.1	0.411
Alt 4	1.1	1/1.6	1/2.1	1	0.177

Seaports connectivity (C34)

	Alt 1	Alt 2	Alt 3	Alt 4	Weights
Alt 1	1	1.4	1.4	1.1	0.298
Alt 2	1/1.4	1	1.6	1/1.1	0.249
Alt 3	1/1.4	1/1.6	1	1/1.5	0.182
Alt 4	1/1.1	1.1	1.5	1	0.271

Environmental impacts from construction (C41)

	Alt 1	Alt 2	Alt 3	Alt 4	Weights
Alt 1	1	1.5	1.4	1.7	0.337
Alt 2	1/1.5	1	1.4	1/1.3	0.224
Alt 3	1/1.4	1/1.4	1	1/1.5	0.187
Alt 4	1/1.7	1.3	1.5	1	0.252

Environmental impacts from operation (C42)

	Alt 1	Alt 2	Alt 3	Alt 4	Weights
Alt 1	1	2.2	1.9	2.1	0.401
Alt 2	1/2.2	1	1/2.3	1/1.3	0.146
Alt 3	1/1.9	2.3	1	1.3	0.262
Alt 4	1/2.1	1.3	1/1.3	1	0.191

Proximity to markets (C51)

	Alt 1	Alt 2	Alt 3	Alt 4	Weights
Alt 1	1	1/1.4	1/3.4	1/1.1	0.154
Alt 2	1.4	1	1/1.7	1/1.4	0.203
Alt 3	3.4	1.7	1	1.9	0.422
Alt 4	1.1	1.4	1/1.9	1	0.221

Government's SEZ/FTA Policies (C52)

	Alt 1	Alt 2	Alt 3	Alt 4	Weights
Alt 1	1	2.4	1.5	1.9	0.337
Alt 2	1/2.4	1	1/2	1/1.6	0.140
Alt 3	1/1.5	2	1	1.7	0.287
Alt 4	1/1.9	1.6	1/1.7	1	0.196

Freight Demand (C53)

The above analysis of matrices are used to derived local weights of the alternative dry ports location with respect to each sub-criteria based on the feedback of the survey. These local weights and weights of five evaluation criteria and sub-criteria are used for synthesis and final weight derivation of the alternative.

Figure 6.8 shows the compiled local weights of the alternative locations with respect to the five main criteria for the combined model (COMB). The outputs are taken from the AHP analysis software – by performing an analysis from the main criteria nodes.

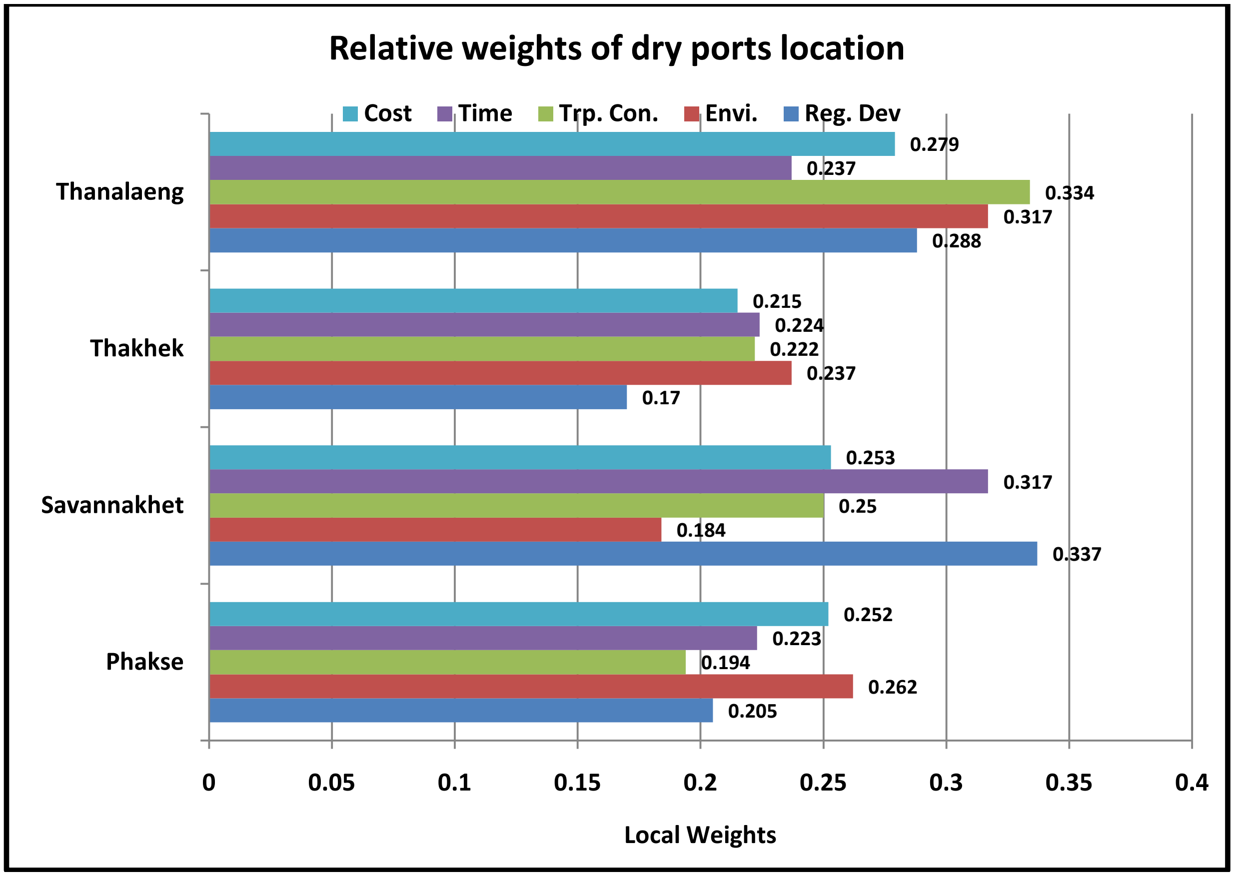


Figure 6.8 Relative weights of alternatives with respect to five criteria (COMB)

6.3.2.4 Evaluation of tangible criteria

Construction cost (C12), transportation time (C21), proximity to market and production centers (C51) and freight demand (C53) are tangible criteria which can be measured. For land acquisition cost (C11) comparison of land cost at different location is used. Sub-criteria transportation cost (C13) is also measurable, but due to sensitivity of the transportation price among freight forwarders and transport operators, it could not be collected and the rating provided by the respondents was used instead. The data for these criteria and sub-criteria was collected during the survey and secondary sources. Table 6.15 shows the tangible data collected and their normalized values which were used for the final analysis. The corresponding values were replaced with the calculated comparison values. Except for 'freight demand' the higher the value of element would lower the resulting weights and priority. For example, higher construction cost of an alternative would encourage decision makers to consider other alternative locations with lower construction costs.

Table 6.15 Estimated values of tangible criteria and sub-criteria

Alternatives	Land acquisition cost (C11)		Construction cost (C12)		Transport time (C13)		Proximity to market (C51)		Freight demand (C53)	
	Ratio	Norm.	M US$	Norm.	Hours	Norm.	Km	Norm.	Tons	Norm.
Thanalaeng	1	0.192	32	0.053	7	0.291	21	0.328	4032000	0.533
Thakhek	0.65	0.295	3.7	0.459	9	0.227	24	0.287	1150000	0.152
Savannakhet	0.8	0.240	4.56	0.373	8	0.255	28	0.246	1577000	0.209
Phakse	0.7	0.274	14.77	0.115	7	0.227	50	0.138	803000	0.106

6.3.2.5 Synthesis and derivation of final priority

The overall synthesis was done using AHP analysis in the distributive mode. The above analysis evaluated the local priorities of four alternative locations. Also in earlier sections, the relative weights of five evaluation criteria and sub-criteria were derived. In the last step of AHP analysis, the global priorities of four alternative locations are evaluated using the global weight of each sub-criterion. This is done by multiplying the corresponding weights and adding up. A relative preference matrix is developed; and corresponding global weights are calculated. For the tangible criteria, the weights derived in Table 6.15 are used. Detail weight derivation and ranking for three different AHP models are shown in Table 6.16**.** Incidentally, the final derived priority of the alternatives is same for all three models, with Thanalaeng receiving the highest priority with weights of 0.311, 0.296 and 0.295 from analysis of government decision makers (GODM), private sector freight forwarders (PSFF) and the combined (COMB) models, respectively. Figure 6.9 shows final derived weight of each dry port location for GODM model.

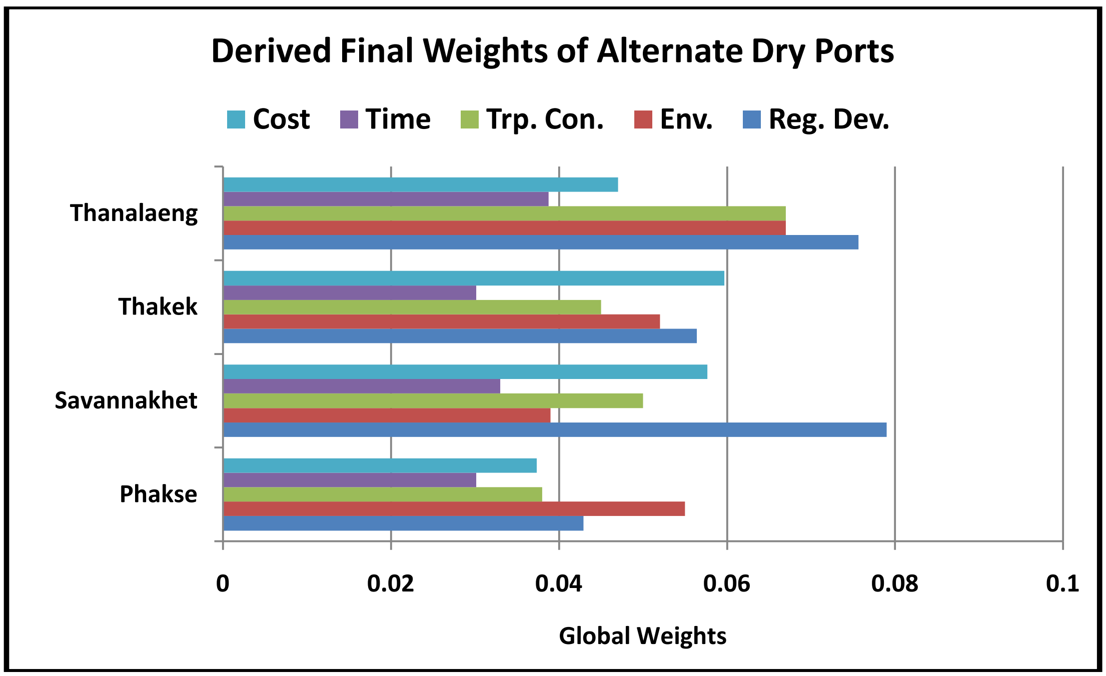


Figure 6.9 Final derived weights of alternative dry ports for COMB model

The overall consistency ratio of the combined model (COMB) is 0.04, consistency ratio of the government decision makers (GODM) model is calculated as 0.02, and the consistency ratio of the private sector freight forwarders (PSFF) model is 0.05. Literatures suggest a value of 0.1 for the consistency index as acceptable and explain consistency of the analysis and outcome. An inconsistency ratio of more than 0.1 may warrant further investigation, in some case, repeat of the survey. Therefore, these values indicate overall consistency of data and analysis and reliability of the outcome.

Figure 6.10 shows the final global weights received by alternative dry ports evaluated with respect to the environmental impact criteria. The analysis clearly shows the preference of Thanalaeng followed by Phakse and Thakhek. The preference of Thanalaeng could be related to the possibility of railway operation as it is connected with railway and possible use of inland waterways. Thakhek is also near Mekong River. Interestingly, Savannakhet received the lowest preference. This could be due the fact that the dry port location, being 24 km inside Mekong River, difficulty in utilizing for inland water transport to the dry port as well as having no firm plan to connect it with railways.

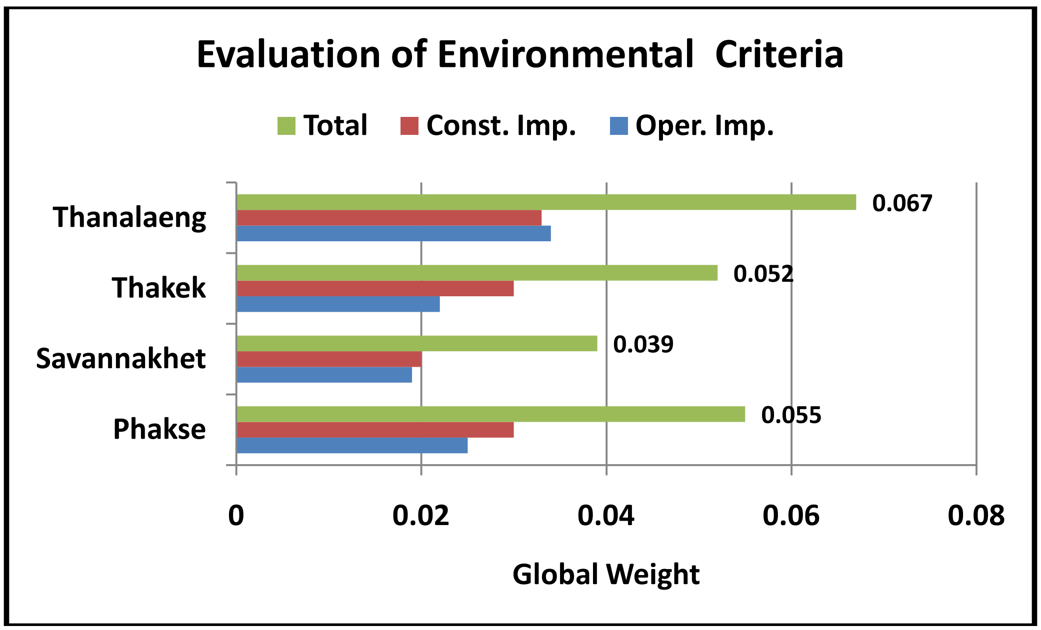


Figure 6.10 Result of synthesis of environmental criteria for COMB model

Figure 6.11 shows final derived weights and ranking of four alternative locations using three different AHP models. The results show that all three location models ranked Thanalaeng as the highest priority location followed by Savannakhet and Thakhek. This result output is in line with the view of policy makers and freight forwarders. The result highlights the importance of Thanalaeng because of its railway connectivity, proximity to Vientiane capital and expected freight volume. Further, Thanalaeng dry port is expected to serve the capital and surrounding area as well with Northern region of Laos.

Table 6.16 Final synthesis and derived weight of alternative dry ports

Criteria\ Location	C11	C12	C13	C21	C31	C32	C33	C34	C41	C42	C51	C52	C53	Total	Rank
Government Decision Makers (GODM) Model															
Thanalaeng	0.0125	0.0045	0.032	0.0361	0.031	0.041	0.01	0.003	0.026	0.025	0.034	0.032	0.024	0.311	**1**
Thakhek	0.0192	0.0386	0.014	0.0281	0.018	0.015	0.008	0.005	0.021	0.02	0.029	0.017	0.007	0.240	**3**
Savannakhet	0.0160	0.0313	0.021	0.0320	0.027	0.011	0.008	0.008	0.016	0.017	0.025	0.023	0.009	0.245	**2**
Phakse	0.0180	0.0097	0.022	0.0281	0.022	0.01	0.008	0.004	0.022	0.022	0.014	0.019	0.005	0.204	**4**
Private Sector Freight Forwarders (PSFF) Model															
Thanalaeng	0.0071	0.0013	0.032	0.0380	0.007	0.02	0.008	0.004	0.051	0.052	0.020	0.015	0.041	0.296	**1**
Thakhek	0.0110	0.0110	0.013	0.0295	0.012	0.01	0.007	0.005	0.048	0.025	0.018	0.032	0.012	0.233	**3**
Savannakhet	0.0090	0.0090	0.022	0.0332	0.012	0.012	0.006	0.009	0.031	0.021	0.015	0.062	0.016	0.257	**2**
Phakse	0.0101	0.0028	0.012	0.0295	0.008	0.008	0.008	0.003	0.051	0.03	0.009	0.035	0.008	0.214	**4**
Combined (COMB) Model															
Thanalaeng	0.0100	0.0030	0.034	0.0388	0.019	0.034	0.01	0.004	0.033	0.034	0.028	0.017	0.030	0.295	**1**
Thakhek	0.0165	0.0262	0.017	0.0302	0.017	0.014	0.008	0.006	0.03	0.022	0.025	0.023	0.009	0.243	**3**
Savannakhet	0.0134	0.0212	0.023	0.0330	0.021	0.012	0.008	0.009	0.02	0.019	0.021	0.047	0.011	0.259	**2**
Phakse	0.0153	0.0060	0.016	0.0302	0.016	0.01	0.008	0.004	0.03	0.025	0.012	0.025	0.006	0.203	**4**

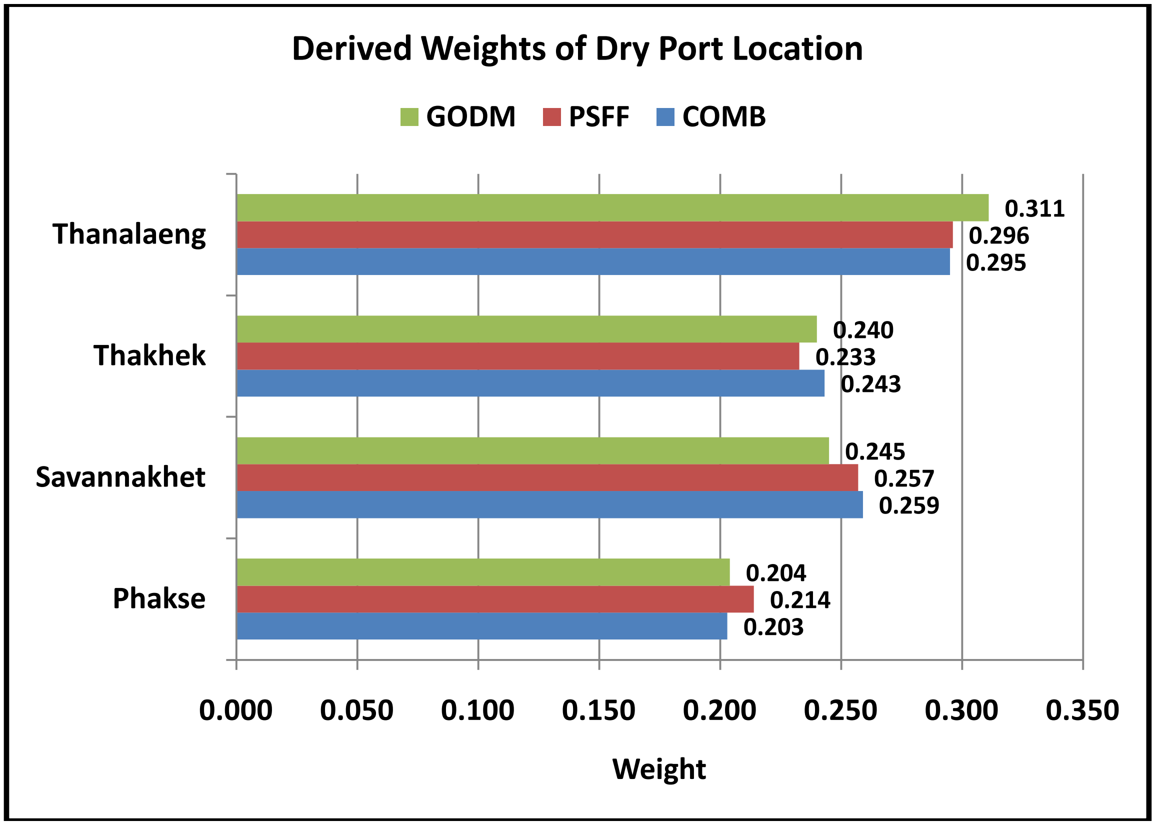


Figure 6.11 Final weights and ranking of alternative dry ports

6.3.2.6 Limitation of AHP analysis

The location analysis was based on the judgment and evaluation of the government decision makers and private sector freight forwarders. For objective criteria and sub-criteria, objective data were used for analysis and comparison of alternative location, wherever possible. The data for total transportation cost (C130) and environmental impacts (C41 and C42) for all alternatives were not available. Therefore, subjective judgments provided by the respondents were used.

6.4 Combined AHP-Goal programming

AHP-Goal programming allows to look at the achievement of the conflicting goals. The five criteria used in AHP analysis were framed as goals of the optimization problem. Thus the goal of the AHP-Goal programming is to select the location(s) that would minimize transportation and operation cost, transportation time and environmental impacts and maximizing the intermodal transport connectivity and regional economic development. For this analysis, the AHP outputs of the combined model are used. This model combines feedbacks received from the government decision makers, private sector freight forwarders and chamber of commerce and industries. All 24 responses received for the AHP analysis are used. Table 6.17 shows the derived weights of five main criteria corresponding to the locations used for analysis of location using AHP. The coefficients were derived based on pair wise comparison on the importance of four alternate dry port locations with respect to each evaluation criterion.

Table 6.17 Derived local weights of main criteria corresponding to alternatives

Criteria	Thanalaeng (X1)	Thakhek (X2)	Savannakhet (X3)	Phakse (X4)
Development and operation costs (C1)	0.279	0.215	0.253	0.252
Transportation time (C2)	0.237	0.224	0.317	0.223
Intermodal transport connectivity (C3)	0.334	0.222	0.250	0.194
Environmental impacts (C4)	0.317	0.237	0.184	0.262
Regional economic development (C5)	0.288	0.170	0.337	0.205

The final weights (priority) of the decision criteria obtained from AHP analysis of combined input of policy makers and freight forwarders is reproduce here in following Table 6.18.

Table 6.18 Final weights of decision criteria of COMB Model

Criteria	Weights
Development and operation costs (C1)	0.202
Transportation time (C2)	0.133
Intermodal transport connectivity (C3)	0.201
Environmental impacts (C4)	0.209
Regional economic development (C5)	0.255
Total	**1.0**

6.4.1 AHP-GP model

Goal programming is used to further analyze the dry port location by considering additional tangible criteria budget constraint and ability to meet the freight demand. By utilizing optimization techniques, the underachievement and overachievement of targeted goals can be assessed, which would be useful for making rational decisions. As outlined in the methodology, using the coefficient of Table 6.17, the Goal Programming model is developed. The main objective of this GP is to minimize the sum of unwanted deviation from the goals. The goals corresponding to the minimization and maximization of the five evaluation criteria becomes constraints of the goal programming objective. The corresponding values are used as the coefficients of corresponding decision variables (location of dry ports), X_1, X_2, X_3, and X_4. Deviation variables are introduced in the left hand side (LHS) of each criterion. Right hand side (RHS) side of the equations for the goals two maximum coefficients are added (Badri 2001, Firouzabadi et al. 2008). This ensures selection of alternatives having combined higher preference (represented by local weights) of all criteria selected.

The final AHP weights derived (Table 6.18) for the evaluation criteria become the weights of the corresponding deviational variables. The objective function is the minimization of sum of deviation variable.

MIN

$$0.202D\_COST\_P+0.133D\_Time\_P+0.201D\_TRN\_N+0.209D\_ENV\_P+0.255D\_RD\_N+ +D\_BDTG\_P+D\_FD\_P+D\_WT\_N \quad (6.1)$$

Subject to,

$$0.279X_1+0.215X_2+0.253X_3+0.252X_4-D\_COST\_P+D\_COST\_N=0.532 \quad (6.2)$$

(Goal relating to development and operation cost)

$$0.237X_1+0.224X_2+0.316X_3+0.223X_4-D\_Time\_P+D\_Time\_N=0.554 \quad (6.3)$$

(Goal relating to total transportation time)

$$0.334X_1+0.222X_2+0.25X_3+0.194X_4-D\_TRN\_P+D\_TRN\_N=0.6 \quad (6.4)$$

(Goal relating to intermodal transport connectivity)

$$0.317X_1+0.237X_2+0.184X_3+0.262X_4-D\_ENV\_P+D\_ENV\_N=0.42 \quad (6.5)$$

(Goal relating to environmental impacts)

$$0.288X_1+0.17X_2+0.337X_3+0205X_4-D\_RD\_P+D\_RD\_N=0.53. \quad (6.6)$$

(Goal relating to regional economic development)

Following three additional constraints are added to meet the requirement of budget and freight demand for 2025. The corresponding coefficients used are taken from the Laos Logistic Study (JICA, 2011).

$$32X_1+4X_2+5X_3+15X_4-D\_BDGT\_P+D\_BDGT\_N=47 \quad (6.7)$$

(Budget constraint)

$$1400X_1+80X_2+150X_3+300X_4-D\_FD\_P+D\_FD\_N=1930 \quad (6.8)$$

(Freight demand)

$$0.295X_1+0.243X_2+0.259X_3+0.203X_4-D\_WT\_P+D\_WT\_N=1 \quad (6.9)$$

(Constraint relating to AHP weights)

$$X_1+X_2+X_3+X_4=>1 \quad (6.10)$$

(Constraint introduced to select at least one dry port location)

All deviation variables are non-negative $DV^{+/-}$=>0

Also, the decision variables X_1, X_2, X_3 and X_4 are 0, 1 variables,

X_i= (0, 1)

Where,
D_COST_P is positive deviational variable for Costs
D_COST_N is negative deviational variable for Costs
D_TIME_P is positive deviational variable for Time,
D_TIME_N is negative deviational variable for Time,
D_TRN_P is positive deviational variable for Intermodal Transport Connectivity
D_TRN_N is negative deviational variable for Intermodal Transport Connectivity
D_ENV_P is positive deviational variable for Environmental Impacts,
D_ENV_N is negative deviational variable for Environmental Impacts,
D_RD_P is positive deviational variable for Regional Development
D_RD_N is negative deviational variable for Regional Development
D_BDTG_P is positive deviational variable for Budget
D_BDTG_N is negative deviational variable for Budget
D_FD_P is positive deviational variable for Capacity and Freight Demand
D_FD_N is negative deviational variable for Capacity and Freight Demand
D_WT_P is positive deviational variable for weights
D_WT_N is negative deviational variable for weights

Xi- is location of the dry ports, decision variables,

6.4.2 Goal programming model outputs

The Goal Programming model can be solved by using LINDO software[12]. For the solution of the location problem the analysis was done by using LINDO software (student version 6.1). The analysis of the model produced the following outputs as shown in Table 6.19 and 6.20.

Table 6.19 Goal programming model output

S. No.	VARIABLE	VALUE	Interpretation
1	X1	1.0	Thanalaeng is selected
2	X2	1.0	Thakhek is selected
3	X3	1.0	Savannakhet is selected
4	X4	0	Phakse is not selected
	Objective function value = 0.30932		

The model selected Thanalaeng, Thakhek and Savannakhet locations but did not selected Phakse. This is consistent with AHP outputs. The value of deviations for each constraint provides a measure for deviation from goal. The smaller the resulting deviation indicates better model

[12] www.lindo.com

accuracy and outcome. The values of deviational variables are shown in 6.20.

Table 6.20 Values of deviational variable

S. No.	Variable	Value
1	D_RD_P	0.170
2	D_ENV_P	0.159
3	D_WT_N	0.203
4	D_COST_P	0.215
5	D_TRN_P	0.222
6	D_TIME_P	0.223
7	D_BDGT_N	6.0
8	D_FD_N	300.0

The following deviation variables have 0 values:

D_TRN_N, D_RD_N, D_BDTG_P, D_FD_P, D_COST_N, D_TIME_N, D_ENV_N, D_WT_P

Based on the outcome, the goals corresponding to the regional development, environmental impacts, transportation cost, intermodal transport connectivity and transportation time resulted in positive deviation variables. This indicates that overachievement of the goals. The target values for goals were set by adding the best two corresponding coefficients. This is due to the model selected three locations. The deviation variables relating to budget, freight demand and AHP weights constraints resulted in negative deviation variable, indicating underachievement. The negative deviational variable for budget and freight demand are 6 and 300 respectively, which corresponds to the dry ports at Phakse- which was not selected by the GP model. Also, the negative weight corresponds to the AHP weight of Phakse.

Thus the combined AHP-Goal Programming methodology can further enhance the prioritization process by addition of other system and resource constraints. The difference of the two approaches is: while AHP result is based on the preference of stakeholders; the AHP-GP utilizes the outcome and enables to prioritize location considering other constraints, and the decision makers can set the achievement level which is right hand side of equation representing goals.

6.5 Results and discussion

The modules 2 of the integrated methodology for location analysis of dry ports included AHP and goal programming. It provided a framework to evaluate and analyze complex problem involving both qualitative and quantitative information. The qualitative information received from the respondents was converted to numerical values based on their judgments.

Interestingly, analysis of all three models returned the same results. The output from the AHP showed high ranking for Thanalaeng, AHP-GP model also selected Thanalaeng, as well as Thakhek and Savannakhet. This is more of the reflection of priority of policy makers and private sector including freight forwarders. Savannakhet, which is located along the GMS East-West Corridor, ranked second and this outcome support ongoing policy initiatives to promote development of the Seno-Savana Free Economic Zone (SSFEZ). The Third Mekong River Bridge connecting Thakhek and Nakhon Phanom in Thailand was recently completed and opened for traffic on 11 November 2011. The opening of the bridge is expected to increase further the importance of Thakhek dry port which was ranked third. Phakse scored lowest rank in all three models. It could be because this is much to support local market and bilateral trade with Thailand. Trade and connectivity with Cambodia is not well developed. It is also interesting to see the outcome of the combined model (COMB) as well as government policy makers' (GDM) and private sector freight forwarders (PSFF) models returned same outcome.

The integrated methodology applied in the case of Laos showed consistent output and its ability to provide decision makers views of various stakeholders. The overall high importance given to the transport connectivity, regional development and environmental impacts shows the strength of the analysis – which are mostly intangible –otherwise thus would have been overlooked in such analysis. The goal programming outputs showed the consistency and strength of the analysis. It can incorporate users (policy makers) defined goals and targets in the analysis. It also enabled to add other system constraints such as AHP weights, budget and freight demand. In the analysis, the goals were set to select the alternative(s) that have combination of highest preference of five criteria (the right hand side of the goals were set by adding two highest weights of each criterion).

The consistency of feedback and analysis was noted while deriving local priorities of alternate dry ports location based on criteria. The analysis also showed a particular preference or high priority given to an evaluation criterion by separate stakeholders. For example, the analysis of feedback from the government policy makers showed the high priority assigned to the regional economic development (weight 0.239), followed by costs and intermodal transport connectivity and the transportation time (weight 0.124) received the least priority. Interestingly, the analysis of feedback from the freight forwarders showed the high priority to the environmental impacts (weight 0.309) followed by the regional economic development (weight 0.283).Transportation time received the lowest priority (weight 0.130). The analysis of combined input showed high preference to the regional economic development (0.255), followed by the environmental impacts (0.209). The above results show that time and costs are not only criteria for analyzing dry port locations; there are other important criteria that need to be considered. This shows some deviation from general perception about cost and time.

The importance given to the environmental impacts by the freight forwarders could explain their capacity to visualize the real impacts as they work on the field. It also could be that the government policy makers are aware of concerns but they could not visualize the impacts of their policies. This is one area needing attention to raise awareness of policy makers on the issues of environmental impacts and climate change. This is also consistence with finding of the survey of policy makers on climate change impacts.

The consistency of the evaluation and analysis was also noted while comparing preference of alternate dry port location with respect to a criterion and sub-criterion. For example, Thanalaeng received low score while synthesizing the land acquisition cost due to high land price in Thanalaeng. While it received high score while synthesizing the intermodal transport connectivity as it is connected by road, railway and inland waterways.

It would be good to include many other evaluation criteria for the location analysis. Appendix-I include a compiled list of factors/criteria and sub-criteria used for location analysis. But due to complexity of the analysis and the need for many questions, five criteria and 12 sub-criteria were used. This also required 101 questions. One lesson from the survey was to pursue for feedback while meeting a respondents-even by rescheduling appointment and extending survey duration if necessary. In many cases, while approaching the potential respondent requested to send questionnaire by email with a promise to reply but many never replied - even after repeated follow-ups.

AHP-Goal programming allowed to look at the achievement of the conflicting goals. The five criteria used in AHP analysis were framed as objective of the optimization problem. Thus the objective of the AHP-Goal programming was to select location that would minimize transportation cost, transportation time and environmental impacts and maximizing the intermodal transport connectivity and regional economic development. In addition it helped to analyze the real case in Laos considering the constraints of budget and freight demand of each potential location. The outcome was consistent with the AHP outputs and general belief of the stakeholders. During discussion with stakeholders in Laos, they confirmed the priority assigned and importance of Thanalaeng and Savannakhet.

6.6 Chapter summary

This chapter applied modules 2 of the integrated methodology and provided details on analysis of primary data collected for the analysis of location of dry ports in Laos using AHP and goal programming. The outcome of both analyses was consistent and Thanalaeng dry port near Vientiane capital received highest priority among other alternative location. This also indicates the consistency of feedback of the government policy makers and private sector freight forwarders in evaluating the dry port locations.

Among the four alternate locations, Thanalaeng is now used as a one of the origin/destination location for international freight transport between Laos and Thailand. The other origin/destination location considered is Laem Chabang Port in Thailand. The next chapter outlines the development of mode choice model and analysis.

CHAPTER 7

ASSESSMENT OF FREIGHT MODAL SHIFT AND EMISSIONS

7.1 Introduction

This chapter outlines the data collection through the use of stated preference survey and analysis of data for estimation of a mode choice model. The freight mode shift is estimated by using the utility function and logit model. CO_2 emissions as a result of the mode shift are estimated by bottom-up approach. In order to have a mode shift from road to rail the dry port at Thanalang has be constructed. The life cycle emissions from the constriction of the dry port are assessed and compared with the emissions reduction through mode shift. Finally, results are discussed and the chapter concludes with a summary.

7.2 Data collection

The location analysis of the dry ports in Laos prioritized Thanalaeng (Vientiane) among the four alternate locations. Therefore, Thanalaeng is now used as a one of the origin/destination point for international freight transport between Laos and Thailand. The other origin/destination location considered is Laem Chabang Port in Thailand. The following section outlines details of data collection process, questionnaire development and stated preference survey.

7.2.1 Selection of route, modes, attributes and attributes levels

Currently goods are transported between Laos and Thailand by road using trucks. The railway line between Thailand and Laos (Thanalaeng) is completed and currently passenger train is in operation. There is a plan to develop a dry port/logistics centers in Thanalaeng and discussion are going on between Thailand and Laos to start freight train service in future. Therefore, the mode choice options considered for the analysis are truck and train along the route Thanalaeng-Laem Chabang Port/Laem Chabang Port- Thanalaeng.

Three type of attributes that can be considered for mode choice problems are:

(i) Attributes relating to the mode: time, cost, reliability, safety etc;
(ii) Attribute relating to the shipment: type of goods, dangerous cargo, frequency etc.;
(iii) Attributes relating to the shipper: location, experience, bulk discount offered etc.

The most frequently used attributes for freight mode choice decisions are time, cost and reliability (punctuality) of service which are the attributes relating to the modes. It is good to consider attributes relating to the shipment type but for our analysis standard containerized cargo is considered. The shippers attribute relating to their experience in the logistics, whether they are able to make mode choice decision or not, their perception on the attributes are collected. These are not used in the model but separately analyzed. The main objective of the mode choice analysis is to estimate future share of each mode once the dry ports is developed and once freight rail operation is available. Therefore, only attributes relating to the modes namely time, cost and punctuality are considered. The total transportation cost includes vehicle operation cost, cost of fuel, driver and labour, loading, unloading and handling at ports and dry ports and in case of railway track access fee, handling of container and return of empty containers. In terms of total transportation time it includes time taken from port to dry ports including loading, unloading time, driving time, time taken at the border crossing. Table 7.1 shows the route, modes, attributes and level.

Table 7.1 Route, choice and attributes level

Route	Vientiane (Thanalaeng)- Laem Chabang Port
Mode choice options	Truck and Train (Labeled)
Modes attributes	Total Transportation cost, Total Transport Time, Punctuality of service
Attributes level	Three for each attribute

7.2.2 Pilot survey to determine attributes levels

A pilot survey of freight forwarders in Laos and Thailand was done during 1-12 September 2011 to determine levels of each attributes and sensitivity of variation of attributes to assign at different levels. 10 freight forwarders in Thailand and Laos, as well as State Railway of Thailand (SRT) were selected for the pilot survey. The respondents of the pilot survey were requested to provide estimate of total transportation time and total transportation cost as well as break-down for freight transport by truck and train between Vientiane (Thanalaeng) –Laem Chabang Port / Laem Chabang Port -Vientiane (Thanalaeng). The pilot survey also included questions on time and cost sensitivity, providing variation of cost and time and punctuality variation range for transportation by truck and train and asking whether they would you change your decision to choose a mode. For punctuality range, the respondents were requested to their preference of range classification with option of time delays for high, medium and low punctuality.

7.2.2.1 Estimation of freight train speed

As there is no freight train in operation, in order to establish the value of travel time attribute of freight train it is necessary to estimate average speed of freight train. The ESCAP study indicates 670 Km length from Vientiane to Bangkok port and cost of US $ 700 time taken by truck is from 17.76 hours to 31.25 hours for transport from Vientiane to Bangkok. It however, notes different (higher) costs of transport from Bangkok- Vientiane estimated around US $ 1200-1500 (United Nations 2003).

Another ESCAP study (United Nations 2001) mentions that commercial speed of freight block trains would be around 65% of the running speed. The speed of Karachi Lahore block train was 20.3 km/hr, in Malaysia maximum speed of freight trains is allowed from 19 to 26 Km/hr. The commercial speed of Port Klang-Bangkok train is 27 km/hr.

Analysis of various demonstration runs of container block trains by ESCAP gave following average speed 22.5 km/hr (Tianjin-Ulaanbaatar, 2003), 35 Km/hr (Brest-Ulaanbaatar, 2004), 35 km/hr (Vostochny-Malacewicze, 2004) and 29.2 km/hr (Lianyunganag-Almaty, 2004). Also a study shows that the average speed of 20 foot container train from Tashkent –Paris was 27.6

km/hr, Moscow- Paris was 33.1 km/hr (Raballand et al. 2005).

There is also regular container block train between Chittagong Port and Kamalapur ICD in Dhaka, Bangladesh. It takes about 12 hours to travel 320 km which gives the average speed of the block train as 26.67 km/hr. Between Laem Chabang Port and Lat Krabang ICD, 12 scheduled container block trains operate in both direction. Depending on the time of departure, the total time taken by the block train varies from 3 to 4 hours for 126 km[13]. Taking average time, this gives average speed of 36 km/hr.

From above, it can be assumed that improved railway freight service in Thailand would have an average speed of 35 km/hr and corresponding time of 22 hour is considered for the freight train service between Laem Chabang and Thanalaeng (Vientiane). Considering 4 hour for loading, unloading time and border checking and clearance process, 26 hours would be the total travel time for freight train.

7.2.2.2 Values of attributes and levels

The values and levels of attributes for mode choice survey are determined based on the feedback received on the pilot survey, interview and discussion with the freight forwarders and railway officials. It also involved collection of data on total freight time and transportation cost of both rail and truck mode transport between Vientiane and Laem Chabang. The base case scenario of total transportation cost and time for one TEU of standard cargo by truck is considered as US $ 1400 and 14 hours, and US $ 800 and time 26 hours by train.

The transportation cost by truck and train is increased by a step $200 to estimate another levels, while the time for truck is increased in a step of two hours and that for train in a step of 4 hours are increased and decreased simply because the total estimated travel time of freight train is almost double to that of truck. In case of punctuality, delivery within 0-8 hours of estimated time is considered as high punctuality, and for other level increased in step of 8 hours for both modes. Table 7.2 shows the attributes and levels for the SP design.

Table 7.2 Attribute levels of choices

Attributes	Truck	Train
Total transport cost	Level 1: US $ 1400 Level 2: US$ 1600 Level 3: US$ 1800	Level 1: US$ 800 Level 2: US$ 1000 Level 3: US$ 1200
Total transportation time	Level 1: 14 Hours Level 2: 16 Hours Level 3: 18 Hours	Level 1: 22 Hours Level 2: 26 Hours Level 3: 30 Hours
Punctuality (Chances of delivery within hours)	Level 1: High (0-8 Hours) Level 2: Medium (9-16 Hours) Level 3: Low(17-24 Hours)	Level 1: High (0-8 Hours) Level 2: Medium (9-16 Hours) Level 3: Low(17-24 Hours)

[13] http:/www.laemchabangport.com/lcp/internet/en/sch.train.php

7.2.3 Design of orthogonal choice experiment

As there are two choices (M=2) and three Attributes (A=3), the degree of freedom is 6+1=7. This gives minimum treatment combination required. As there are two choices (M=2), three Attributes (A=3) and three levels (L=3), it can generate 3^{2X3} = 243 choices. It is not possible to present all these choices to the potential respondents. Therefore, fractional factorial design is employed. Literatures further suggest that maximum choice options that can be offered are 16.

The combination of attributes can be presented to the respondents to estimate the parameters and utility of each mode. The minimum number of treatment combination is necessary for fractional factorial design. Balance orthogonal design is generated by SPSS. A balanced design has each attribute level occurring equally often, and minimizes variance in the parameter estimation (Kuhfeld 2009). In orthogonal fractional factorial design, the parameters estimates in linear model are uncorrelated, which means that the attributes of the design are statistically independent of each other.

Table 7.3 shows factor factorial orthogonal balanced design generated by using SPSS. It generated 18 scenarios.

Table 7.3 Orthogonal and balanced choice sets generated by SPSS

	Truck			Train			
S. No.	**Cost**	**Time**	**Punctuality**	**Cost**	**Time**	**Punctuality**	**Design**
1	1800	16	High	1000	22	High	A
2	1400	18	Medium	1000	22	Low	B
3	1800	18	Low	800	26	High	A
4	1400	16	Low	800	26	Low	B
5	1600	14	High	800	30	Low	A
6	1800	16	Medium	800	30	Medium	A
7	1600	18	Medium	800	22	Medium	B
8	1600	14	Medium	1200	26	High	A
9	1400	14	Low	1000	30	Medium	B
10	1800	14	Medium	1000	26	Low	A
11	1400	16	Medium	1200	30	High	B
12	1400	18	High	1200	26	Medium	B
13	1800	14	Low	1200	22	Medium	A
14	1400	14	High	800	22	High	B
15	1600	18	Low	1000	30	High	B
16	1800	18	High	1200	30	Low	A
17	1600	16	Low	1200	22	Low	B
18	1600	16	High	1000	26	Medium	A

7.2.4 Development of choice sets and SP questionnaire

Drawing on the experience of AHP survey, in order to ensure more feedbacks and to increase reliability of feedbacks the 18 scenarios are divided into two sets of questionnaire each with 9 choice scenarios. The 9 scenarios to be included in design A and B were randomly selected as show in the last column of Table 7.3**.** The number of scenario to each respondent can range from 1 to 32 (Boxall et al. 1996). Johnson and Devousges (1997) mentioned that up to 26 sets for paired comparison have been presented to the respondents. In the case of research, one questionnaire contains 9 scenarios. Truck and train options are mentioned (labeled) in the questionnaire. In the questionnaire, the value of punctuality was included high (0-8 hours), medium (9-16 hours) and low (17-24 hours). Table 7.4 and 7.5 show the choice scenarios included in questionnaire design A and B respectively.

Table 7.4 Scenarios for questionnaire design A

	Truck			Train		
S. No.	**Cost**	**Time**	**Punctuality**	**Cost**	**Time**	**Punctuality**
1	1800	16	High	1000	22	High
2	1800	18	Low	800	26	High
3	1600	14	High	800	30	Low
4	1800	16	Medium	800	30	Medium
5	1600	14	Medium	1200	26	High
6	1800	14	Medium	1000	26	Low
7	1800	14	Low	1200	22	Medium
8	1800	18	High	1200	30	Low
9	1600	16	High	1000	26	Medium

Table 7.5 Scenarios for questionnaire design B

	Truck			Train		
S. No.	**Cost**	**Time**	**Punctuality**	**Cost**	**Time**	**Punctuality**
1	1400	18	Medium	1000	22	Low
2	1400	16	Low	800	26	Low
3	1600	18	Medium	800	22	Medium
4	1400	14	Low	1000	30	Medium
5	1400	16	Medium	1200	30	High
6	1400	18	High	1200	26	Medium
7	1400	14	High	800	22	High
8	1600	18	Low	1000	30	High
9	1600	16	Low	1200	22	Low

Each questionnaire contained brief introduction of the survey, purpose, and future scenarios. Part I of the questionnaire presented 9 scenarios in the format shown in Figure 7.1. Part II of the questionnaire contained 9 questions seeking details of the respondent's gender, age, education, experience in the logistics sector, role in making mode choice decisions, perception on importance of time, cost and punctuality, would they consider using freight train if available, and views on importance of dry ports/logistics centre in promoting mode shift and intermodal transport. This also provides a break of momentum from choosing scenarios presented – if the respondent agreed to provide feedback to the other set of questionnaire. Both sets of questionnaire design A and Design B are attached as Appendix-IV.

Attributes ↓ Mode →	Truck	Train
Travel Time	16 Hours	26 hours
Transportation cost/TEU	US$ 1600	US $ 1000
Punctuality	High (0-8 Hrs)	Medium (9-16 hrs)
Which option would you choose (please select one box)	☐	☐

Figure 7.1 Format of the choice scenarios presented in the questionnaire

7.2.5 Stated preference survey

7.2 5.1 SP survey of freight forwarders in Thailand

During face to face interview the respondents were asked to consider transportation of standard and normal one TEU container – non- hazardous and non-dangerous cargo. The face to face survey in Thailand was conducted during the Thailand International Logistics Fair held in Bangkok during 23 to 25 September 2011. It provided opportunity to meet and interview many freight forwards at one location. Total 16 responses were received during the logistics fair. Some freight forwarders requested to send questionnaire by email. The questionnaires were sent by email as well and were followed-up through repeated reminders and calls. Some replies were received by email.

Second round of face to face interview was conducted by visiting freight forwarders office in Bangkok during 13 - 20 October 2011 and after calling for appointments, this time also some requested by email and both set of design A and B was sent to the freight forwarders. Total 23 completed surveys were collected from Thailand.

7.2.5.2 SP survey of freight forwarders in Laem Chabang Port

A survey of freight forwarders in Laem Chabang area and a visit to the Port Authority of Thailand was conducted on 7 November 2011. During the visit to the block train station yard, port facilities were observed and discussion was held with the Laem Chabang Port officials. Figure 7.2 shows the starting point of the block trains to the Lat Krabang ICD and a view of the Laem Chabang port. 12 scheduled container block train leaves Laem Chabang port for Lat Krabang ICD and 12 block trains returns from ICD. Depending on the time of departure the total time taken by the block train varies from 3 to 4 hours for 126 km. Also, face to face interview were conducted with freight forwarders. Total 10 responses from 5 freight forwarders were received including 2 received by email.

Figure 7.2 Block train to Lat Krabang ICD and Laem Chabang Port

7.2.5.3 SP survey of freight forwarders in Laos

Contact was maintained with LIFFA to help for the survey in survey with a request to seek appointments with freight forwarders. Questionnaire survey in Vientiane was undertaken during 20-23 October 2011. Questionnaires were sent to all LIFFA members prior to the visit. Interview surveys were carried out on 21 and 22 October through visiting freight forwarders office. Telephone calls were placed again to confirm the appointments and seek new appointments. Some freight forwarders were out of Vientiane and they informed that they will reply to email request. Emails were sent to them. A local assisted in visits and translation, whenever required. During survey, nine face to face interviews returned 18 replies (both set A and B). 8 replies from 4 freight forwarders were received by email. Thus total responses were from 13 freight forwarder (out of total 22 members of LIFFA). These represent about 59% replies from potential population in Laos.

7.2.5.4 Summary of stated preference survey

Table 7.6 shows details of response received from the SP survey and valid replies and data sets. Total 59 questionnaires were returned from 34 freight forwarders that included 33 replies from Thailand and 26 replies from Laos. This gives total data sets of 59X9= 531.

Table 7.6 Summary of response received on SP Survey

Survey location	**No of freight forwarders replying**	**Number of questionnaires returned**	**Total data sets**
Thailand	21	33	33X9=297
Laos	13	26	26X9=234
Total	**34**	**59**	**531**

2 questionnaires were incomplete and there were 14 biased replies towards a mode, where a respondent selected only one mode in whole questionnaire. These were not included in analysis and total data set used for analysis is 43X9=387.

7.2.6 Limitation of the SP survey

The flood situation in Thailand during October –November 2011 constrained the outcome of the survey and limited access and travel to Lat Krabang and opportunity to meet many freight forwarders. As indicated above many freight forwarders in Laos and Thailand requested to send the questionnaire by email and promised feedback. But the email response was not as anticipated as only few replies came by emails even after repeated email reminder as well as telephone calls.

Some bias of freight forwarders owning fleet of truck was noted. One of the important aspects of freight transport by train was raised during the survey in Laos. It is - why passenger and freight train cannot be combined? The example cited was – planning a train's half of the wagon/bogie for passenger and half of the bogie/wagon for fright. Was it the question of security? The view was this could make freight transport feasible when there is not enough freight volume to start regular freight trains.

Another aspect raised during the interview was relating to the truck owners lobbying power. In some case they could have strong lobbying power that can influence government logistics policies that are favourable to truck at the cost of rail mode. During interview, many freight forwarders mentioned that the choice also depends on the traders, manufacturers and clients and suggested to seek their views as well.

7.2.7 Interview with policy makers and freight forwarders

In addition to the structured questionnaire survey as outlined above, during the course of research in depth unstructured interviews and discussions were held with policy makers, international freight forwarders (TIFFA and LIFFA), Thai Ship-owners Association and transport professionals in Laos and Thailand as well as at international forums. The main objectives of these interviews and discussion were to understand their future transportation and logistics plan, there perception on modal shift, roles of private sector and government in integrating transport modes, expectation of private sector in facilitation of international import and export. Further, in depth discussion was held with the officials of State Railway of Thailand, Marketing Department to understand their plan of starting freight train service, future expansion of railways to other border of Laos.

7.2.8 Outcome of the stated preference survey

The respondents were requested to select a mode in various mode choice scenarios. The respondents were also asked general questions about themselves and related to their experience in the logistics industry and making mode choice decisions. The gender, age and distribution of the respondents as well as their feedback are summarized below.

(i) Gender and age of the respondents: Figure 7.3 shows the age, gender and experience of the respondents. Majority of respondents were male representing about 80% of the response received. This may be due to logistics industries are dominantly managed by men. It indicates the need to encourage women to pursue careers in the logistic industry. In terms of age group, majority fall in the category of 31-40 years and 51-60 years category. Also, the majority of respondents were with more than 15 years of logistics experience (47%), followed by those having experience up to 5 years. This can attribute to the reliability of responses owing to their experience in making mode choice decisions.

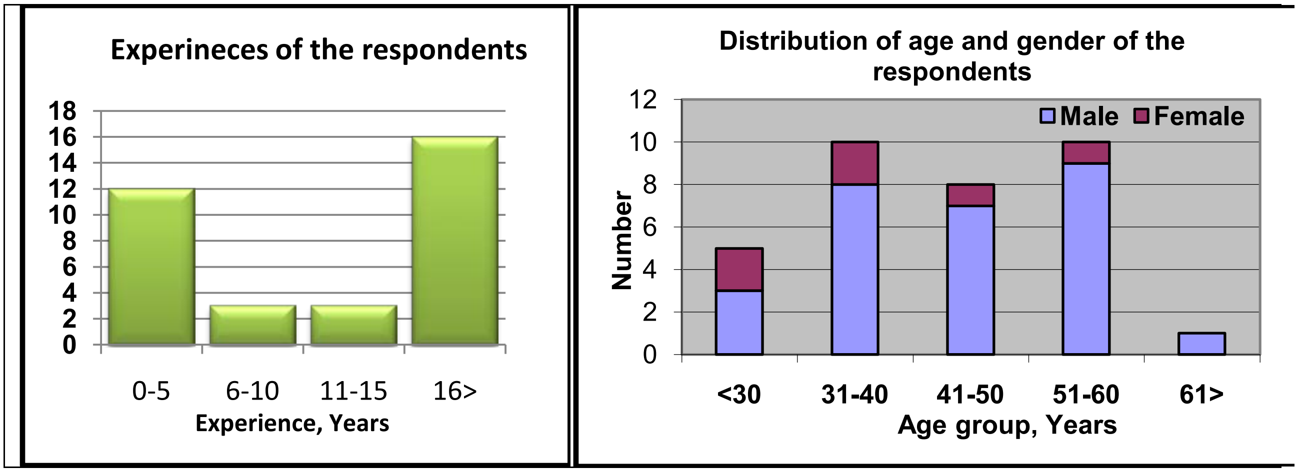


Figure 7.3 Age, gender and experience of the respondents of SP survey

(ii) Do you make mode choice decisions and consider using railway for freight? Figure 7.4 shows the respondent's replies to questions on whether they would make mode choice decisions and consider using railway for freight if regular service is available. 57% of the respondents replied that make mode choice decisions and 86% of the respondents said that they would use railway for freight transport. This clearly shows the need to introduce the freight train services. Further, during discussions many respondents raised the issues of possibility of combining passenger and freight train to start freight service as early as possible. This is of particular importance as the current freight volume may not be enough for full container block train with 30-40 containers.

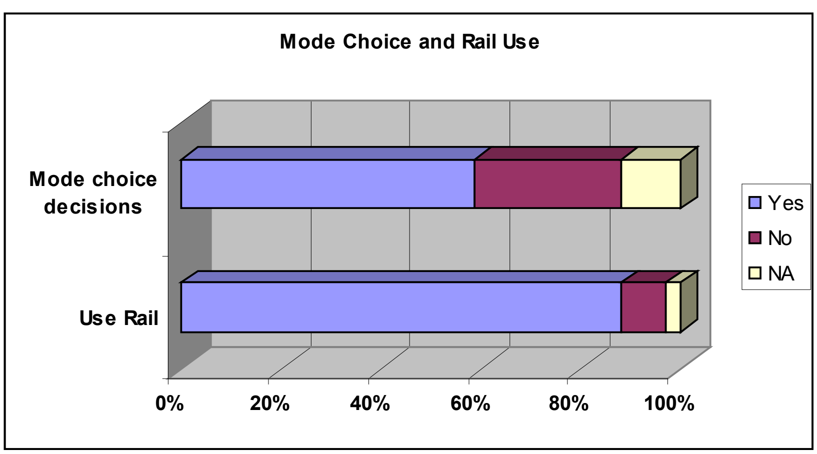


Figure 7.4 Mode choice decision and railway use[14]

[14] NA=No answer

(iii) Importance of time, cost and reliability: The respondents were also asked to rate importance of three attributes that can influence mode choice decisions. As there were three attributes, the respondents were asked to rate in order of importance 1, 2 and 3. Figure 7.5 shows the respondents perception on the importance of transportation cost, transportation time and reliability in making mode choice decision. The rating is converted to a weighted average score in a three points scale. The transportation cost scored high with 2.55, transportation time stood second with 2.31 and reliability stood third with 1.62 score. This clearly indicates the importance of cost, time and reliability in making mode choice decisions.

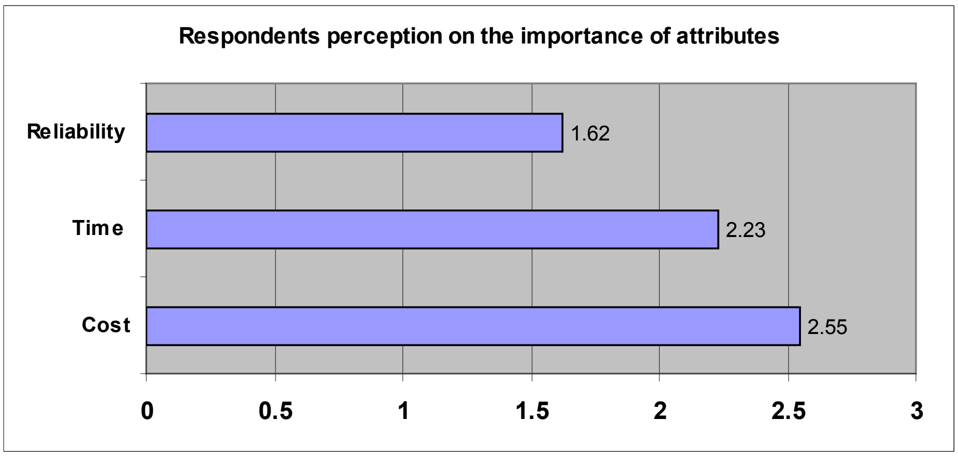


Figure 7.5 Respondents perception on rating of cost, time and reliability

Respondents further mentioned that other factors important for mode choice decisions are insurance, damage to cargoes, safety, delivery, train schedule, security, trucking and tracking system and connectivity to other modes of transport.

(iv) Importance of logistics centres/dry ports: The respondents highly rated the importance of dry ports for encouraging intermodal transport and modal shift. On a five point scale it received aggregate the score of 3.77. This indicates that the logistics centres and dry ports can significantly influence mode choice decisions as they integrate and connect different modes of transport are connected/integrated thus providing modal shift opportunities.

7.3 Mode choice model

The data collected from freight forwarders in Laos and Thailand is tabulated and analyzed to estimate mode choice parameters. Module 3 of the integrated methodology is used for analysis. Discreet choice model with two choices options are used. All three variables are considered as generic parameters for total time, costs and reliability (delay) are estimated. A model constant is estimated for truck mode.

7.3.1 Estimation of model parameters

The attributes and levels have been limited to three and so as not to overwhelm the respondents with too many choices. The collected data are tabulated in NLOGIT format. There are options to estimate mode specific constants and generic constant. NLOGIT/ LIMDEP software (Greene

2008) was used to estimate the model. Among the total 59 survey response received (total 531 data sets) 43 valid responses[15] with total data sets of 387 are used in analysis.

Initially parameter estimation was done including alternate specific constant (ASC) for truck mode and generic parameters corresponding to time, cost and reliability of both modes truck and train. The utility functions are expressed as shown equations 7.11 and 7.12.

$$U(TRUCK) = A+B*TIME+C*COST+D*DELAY \quad (7.11)$$

$$U(TRAIN) = B*TIME+C*COST+D*DELAY \quad (7.12)$$

Where,
U(TRUCK)- observed utility value of truck
U(TRAIN) – observed utility value of train
TIME- total transportation time
COST- total transportation cost
DELAY- reliability of truck service (measured in average delay to the scheduled time)
A is mode specific constant for truck
B is generic parameter corresponding to transportation time
C is generic parameter corresponding to transportation cost
D is generic parameter corresponding to reliability (delay) of service.

While estimating three parameters as generic variables, the results showed the significance and negative signs for all parameters for cost, time and delay as expected, but the alternate specific constant for truck was not statistically significant (t-value-0.222 and p-value-0.8245) and returned much higher error as shown in Table 7.7. As constant term is important for binomial model than can explain errors terms that is not covered by the attributes considered for the model formulation. Further, the negative sign of the constant term indicated that some preference to the train mode given all other condition remaining the same.

Table 7.7 Estimated generic model parameters

Variable	Coefficient	Standard Error	t-value	P-value
ASC_TRUCK (A)	-0.0953	0.4298	-0.222	0.8245
TIME (B)	-0.1691	0.0320	-5.282	0.0000
COST (C)	-0.0028	0.0005	-5.241	0.0000
DELAY(D)	-0.0660	0.0136	-4.853	0.0000

Number of observation= 387

Log likely hood function (L) = **-**227.1740
Log likely hood only constant (L_0) = -268.1846
McFadden likelihood ratio index (ρ^2_M) = 1-Log L/Log L_0 = 0.1529

[15] 2 incomplete and 14 biased replies towards a mode, where respondent selected only one mode in whole questionnaire were not included.

Adjusted likelihood ratio (ρ^2_M) =0.1441
Chi-squared (χ^2) = 82.0214

The model could be used omitting the insignificant mode specific constant (A_TRUCK). This would mean that the responded did not consider the other unobserved factors while selecting a mode or they considered other factors however their influence on mode selection decision was insignificant. Further, as currently the mode share of truck is 100%, a positive sign of the mode specific constant for truck is normally expected.

Therefore, in order to increase the reliability of the model, the data are again analyzed to estimate alternative specific constant and different mode specific parameters. The following utility equations 7.13 and 7.14 are defined in the NLOGIT:

U(TRUCK) = A1+B1*TIME+C1*COST+D1*DELAY (7.13)

U(TRAIN) = B2*TIME+C2*COST+D2*DELAY (7.14)

Where,
U(TRUCK)- observed utility value of truck
U(TRAIN) – observed utility value of train
TIME- total transportation time
COST- total transportation cost
DELAY- reliability of truck service (measured in average delay to the scheduled time)
A1 is mode specific constant for truck
B1 is mode specific parameter corresponding to transportation time of truck
C1 is mode specific parameter corresponding to transportation cost of truck
D1 is mode specific parameter corresponding to reliability (delay) of truck service.
B2 is mode specific parameter corresponding to transportation time of train
C2 is mode specific parameter corresponding to transportation cost of train
D2 is mode specific parameter corresponding to reliability (delay) of train service.

In this case, the results show that the significance of alternate specific constant and other parameters is greatly improved and estimated parameters values show significance at 95% indicated by t-values. Only, the parameter for the cost of truck (C1) shows less significance than other variables but still acceptable at 89% level of significance.

Table 7.8 Estimated model parameters

Variable	Coefficient	Standard Error	t -value	p-value
ASC_TRUCK (A1)	-4.6704	2.1335	-2.189	0.0286
TIME_TRUCK (B1)	-0.1365	0.0740	-1.844	0.0652
COST_TRUCK (C1)	-0.0011	0.0007	-1.565	0.1175
DELAY_TRUCK (D1)	-0.1015	0.0187	-5.413	0.0000
TIME_TRAIN (B2)	-0.1791	0.0355	-5.044	0.0000
COST_TRAIN (C2)	-0.0047	0.0008	-6.040	0.0000
DELAY_TRAIN (D2)	-0.0386	0.0182	-2.114	0.0345

Number of observation=387

Log likely hood function (L) = -217.3192
Log likely hood only constant (L_0) = -268.1846
McFadden likelihood ratio index (ρ^2_M) = 1-Log L/Log L_0 = 0.1897
Adjusted likelihood ratio (ρ^2_M) = 0.1747
Chi-squared (χ^2) = 101.7309

We can see from the Table 7.8, all mode specific parameters are significant and have negative signs as expected, indicating an inverse relationship. An increase in values of cost, time and delay would lead to decrees in utility of that mode - meaning the chances of choosing a mode decreases with increase in these parameters. Further, the negative sign of the mode specific constant for truck indicates that in given situation (the dry port and rail service available) the respondents have some preference to train compared to truck. However, due to existing situation a positive sign would have explained the existing situation of 100% truck share and preference towards it. The negative sign of the constant could reflect the respondent's preference for the train as 86% of the respondents have said they would consider using train if freight train service is available. Further, while selecting a mode in a given scenario, the cumulative selection of rail mode was 52%. Also, in binary logit models the goodness of fit is of secondary importance (Gujarati and Porter 2009), the expected signs of regression coefficients and their statistical and practical significance are more important. Greene (2011)[16] also advised that "The rho-squared is not a fit measure. It is simply a function based on how much the log likelihood changes when you add variables to a model that only includes a constant term. It is common for models with large numbers of variables that are highly significant to have quite low values of this statistic."

Further, in order to compare the generic model (Table 7.7) and the model with mode specific parameters (Table 7.8), a chi-squared test was conducted.

Difference in χ^2 of two models=101.73-82.02= 19.71
Difference in degree of freedom (df)=3

[16] Personal email communication with Prof. W. Greene on NLOGIT output, 8 November 2011.

For 3 degree of freedom and p-value of 0.001, the χ^2 value is 16.27; this indicates that the test χ^2 statistics is significant at more than 99.9% level. Thus, we can conclude that the model with mode specific parameters fit the data significantly better than the generic model. Therefore, the later model is used for the further analysis.

The utility functions are given by equations 7.15 and 7.16.

U(TRUCK)=-4.6704-0.1365*TIME-0.0011*COST-0.1015*DELAY (7.15)

U(TRAIN) = - 0.0854*TIME-0.0047*COST-0.0386*DELAY (7.16)

7.3.2 Estimation of probability of choosing a mode

The probability of choosing the rail mode is estimated using the logit model.

$$P(rail) = \frac{\exp(V_{rail})}{\exp(V_{rail}) + \exp(V_{road})} \tag{7.17}$$

The probability of choosing a mode depends on the attributes values selected. From the pilot study for the base case, the transportation on the Laem Chabang –Thanalaeng route by truck takes 14 hours and the cost is US $1400. Similarly, the time taken by freight train is estimated as 26 hours considering total travel time including loading, unloading and border checking and the cost as US $ 800. JICA (2011) also estimated 48 hours for a total round trip. Assuming there is no delay for both modes in base case scenario the resulting utility values are:

U(TRUCK)=-4.6704-0.1365*14 -0.0011*1400-0.1015*0 = - 8.4493

U(TRAIN) = - 0.0854*26-0.0047*800-0.0386*0 = - 8.1758

The resulting mode share is;

$$P(Truck) = \frac{\exp(-8.4493)}{\exp(-8.4493) + \exp(-8.1758)}$$

P(Truck) = 56.8%

P(Train) =1-0.568= 43.2%

This indicates reasonable estimate of mode share by using the model[17] with mode specific parameters. During the survey many respondents have indicated that they would choose railway if service is available. Further, the JICA study had estimated the share of railway to be 49% in

[17] Use of the generic model by omitting the non-significant mode specific constant for truck estimated 58.6% mode for truck and 41.4% train share in base case scenario. This is very close to the mode share estimate by the second model.

2025 using empirical study from Delhi-Mumbai Freight Corridor (JICA 2011) which may not be very relevant in here. Based on the survey, the results indicates that the freight forwarders have high expectation from future freight railway service as the estimated mode share is slightly less than 50% which currently is being transported 100% by trucks.

Tsamboulas and Moraitis (2008) developed a methodology for estimating fright mode shift of an intermodal corridor and applied it to the transportation corridor from the Black Sea to the Greek port. The mode share attracted by the intermodal corridor was 21%, 22% and 50% depending on the combination of train and maritime route considered. Feo-Valero et al. (2011b) modelled choice between road only mode and road and rail transport mode for the inland leg transport from port of Valencia and Madrid in Spain considering time, cost and reliability and found that parameters are generic for both modes and show preference of using road.

7.3.3 Elasticity of time and cost

As indicated by equation 7.15 and 7.16 the utility value of a mode depends on the values of attributes. Thus, the mode share also depends on utility values of the modes. As the mode share is estimated for future scenarios, the following scenarios are considered and mode share estimated. The effect on mode share due to the percentage variation in transportation cost, transportation time and delay are considered. Table 7.9 shows the level of change of the attributes.

Table 7.9 Attributes and level of changes for determining elasticity

Attributes	Mode	Level of changes			
Total Cost	Truck	-10%	-20%	10%	20%
	Train	-10%	-20%	10%	20%
Total Time	Truck	-10%	-20%	10%	20%
	Train	-10%	-20%	10%	20%
Cost and Time	Truck	-10%C, +10%T	-20%C, +20%T	10%C, -10%T	20%C, -20%T
	Train	-10%C, +10%T	-20%C, +20%T	10%C, -10%T	20%C, -20%T
Reliability	Truck	-10%	-20%	10%	20%
	Train	-10%	-20%	10%	20%

All of the above level of changes on time and cost are not practical. They have been arbitrarily chosen to draw the elasticity graphs. While estimating resulting CO_2 emission, only the practical values are taken that range increase and decrease in 10% variation in time and cost. While increase in 10% cost and time for the freight transport by train and truck in the route is possible. This could be due to decrease in speed of truck and train, increase in handling and loading time at port and dry port. Also delay due to poor condition of road and railway tracks and border crossing procedure. Among these, some of these transport operators do not have control over condition of route and border clearance so these are external factors. While cost could increase due to increase in fuel price, driver's cost, labour cost that affect container and cargo handling at port and dry ports. Another way to analyze is using existing vehicle operation cost (VOC) model for both modes.

Reduction of cost could be possible if the railway uses electric traction. This would also reduce average emission factors. Other way to reduce cost would be to secure bulk transportation contracts and ensuring of cargo loads in both transport legs can reduce overhead and have effect on price. As railways is more energy efficient and emit fewer emissions than truck- one way to influence the mode choice decision is to provide subsidies to railways through reduced fuel price for railway. This could reduce the cost of transportation make railway more attractive. Such practice has been used and being used in Europe.

For other value of variation in time and cost, the corresponding variation on mode shift can be estimated by taking direct reading from the elasticity graphs.

7.3.3.1 Variation in mode share due to cost variation

The model has mode specific parameters; therefore, the elasticity was conducted to look at the effect of percentage cost variation of truck and train on the mode share. The results show that a 10% reduction of cost of truck mode would increase its mode share by 3.9% thereby decrease the rail share by same amount. Similarly, 10% increase in the transportation cost of truck would reduce its mode share by 3.9%. In case of train a 10% reduction in transport cost would increase its mode share by 9.4% whereas a 10% increase in transportation cost would reduce its share by 9%. Figure 7.6 shows the elasticity graph which is linear.

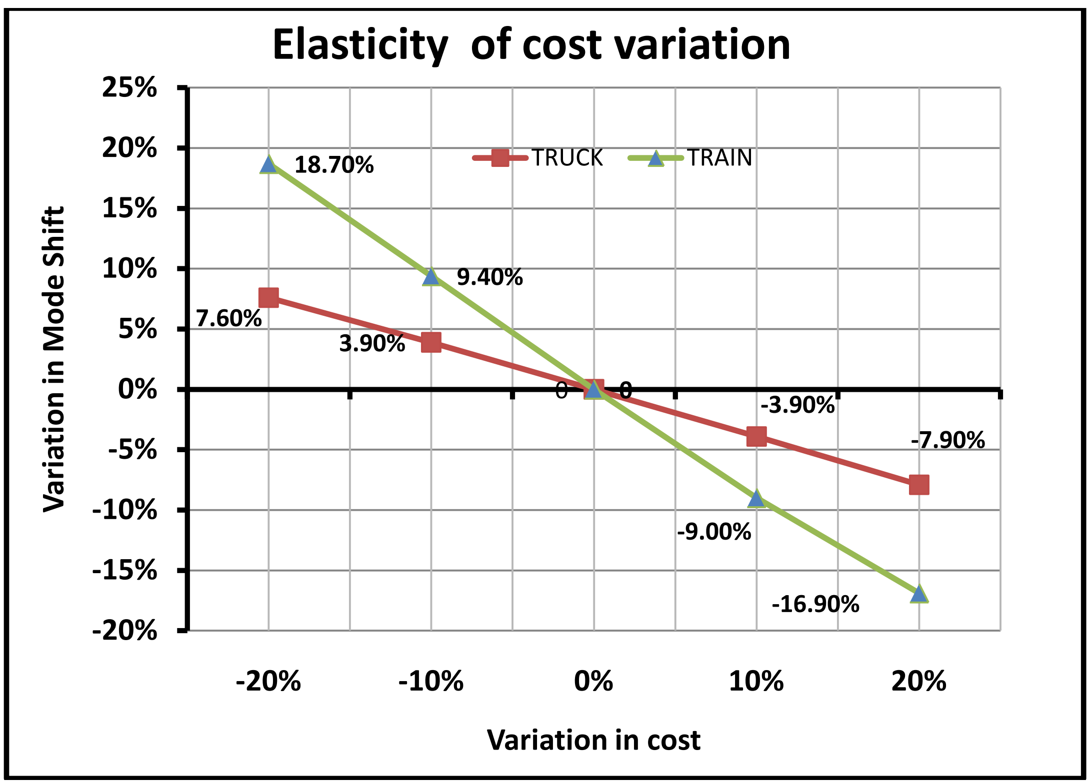


Figure 7.6 Elasticity of mode share due to cost variation

7.3.3.2 Variation in mode share due to time variation

The effect of variation in total transportation time on mode share was also evaluated. The results show that a 10% reduction of total transportation time of truck would increase its mode share by 4.6%, thereby decreasing the rail share by same amount. Similarly, 10% increase in the transportation time of truck would reduce its mode share by 4.7%. In case of train, a 10% reduction in transportation time would increase its mode share by 11.6% whereas a 10% increase in transportation cost would reduce its share by 10.9%. Figure 7.7 shows the elasticity graph of the variation in time.

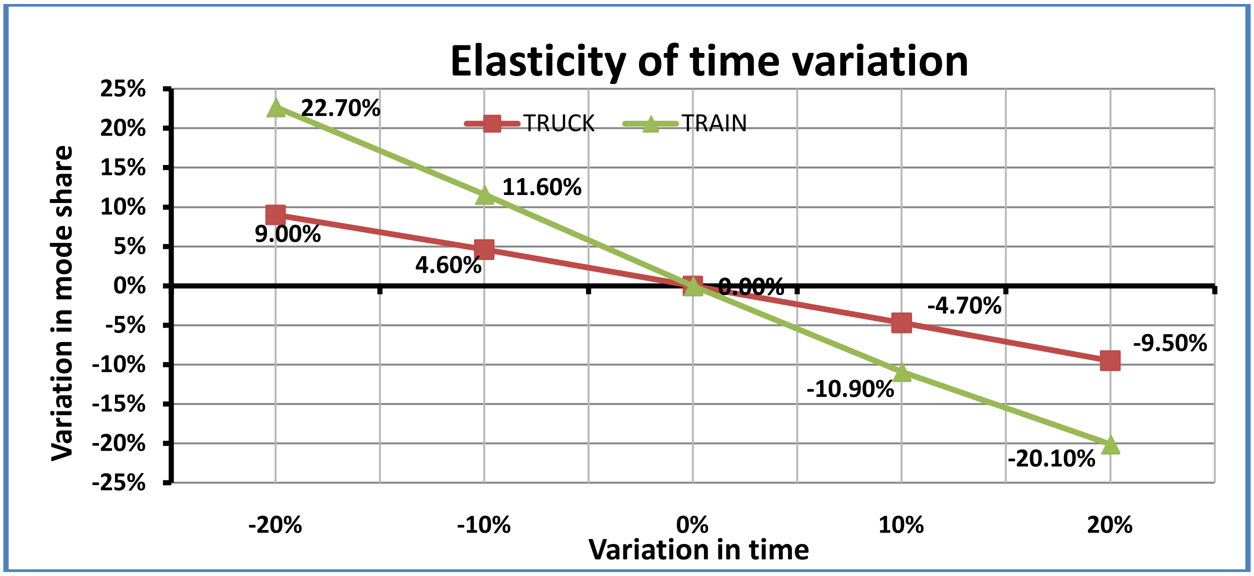


Figure 7.7 Elasticity of mode share with variation in transportation time

7.3.3.3 Variation in mode share due to cost and time

The above cases looked at the elasticity of the cost and time independently on the mode share. There is a tradeoff between cost and time. The total transportation time can be reduced by using reliable and urgent service by paying more. Similarly, if the cost is a concern and a customer wants transportation cost to be low then shipment transportation time would be more as the shipment would be assigned a low priority. To evaluate the trade off, a combination of time and cost variation was evaluated to see its effect on the mode share. The results were not much encouraging. A combination of 10% increase in cost of truck transport and 10% reduction in transport time showed only 0.8% increase in mode share of truck. This is almost like a 10% tradeoff between cost and time in case of truck mode. Similarly, a 10% decrease in transportation cost of train and 10% increase in time showed a decrease of 2.1% mode share of train. This indicates that in case train time is more sensitive than cost for mode share. Figure 7.8 shows the elasticity of combined time and cots variations.

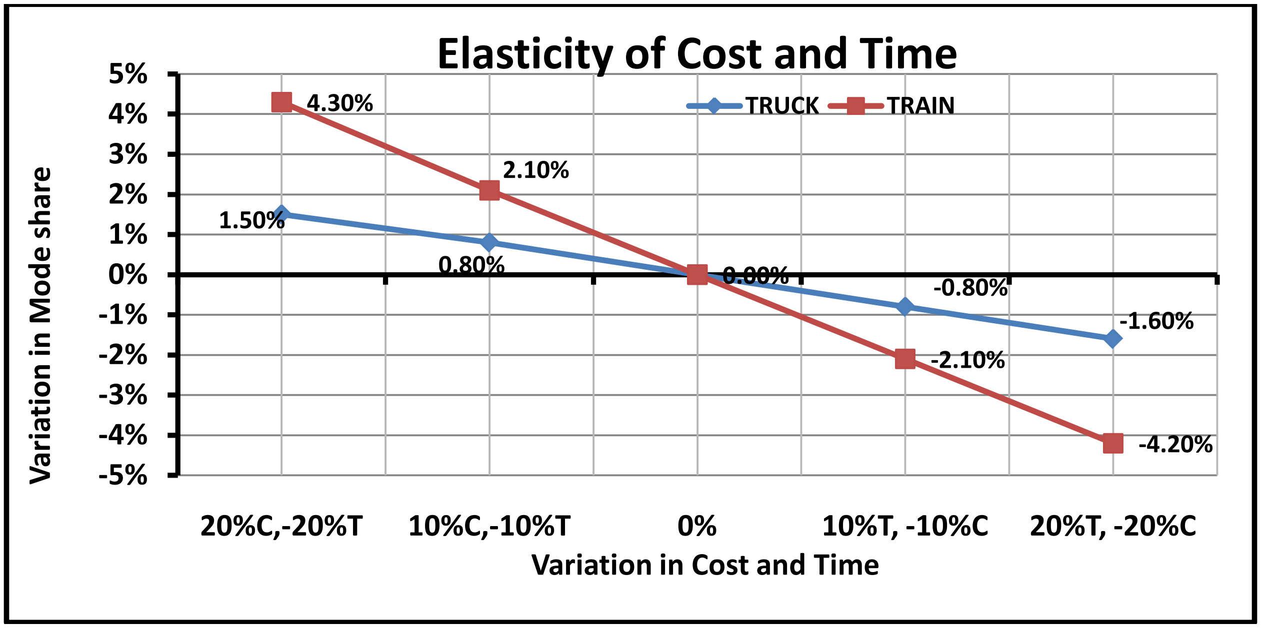


Figure 7.8 Elasticity of mode share with cost and time variation

7.3.3.4 Variation in mode share due to reliability

The effect of reliability measured by delay in scheduled delivery of cargo on mode share was also evaluated. The results show that a decrease in reliability (delay by 1.4 hours) of truck transport would reduce its mode share by 3.5% thereby decrease the rail share by same amount. Similarly, increase in reliability of the truck mode (early arrival by 1.4 hours) would increase its mode share by 3.4%. In case of train a 10% reduction in reliability of the mode would decrease its mode share by 2.4% whereas a 10% increase in reliability (early arrival) would increase its share by 2.5%. Figure 7.9 shows the elasticity of reliability (delay).

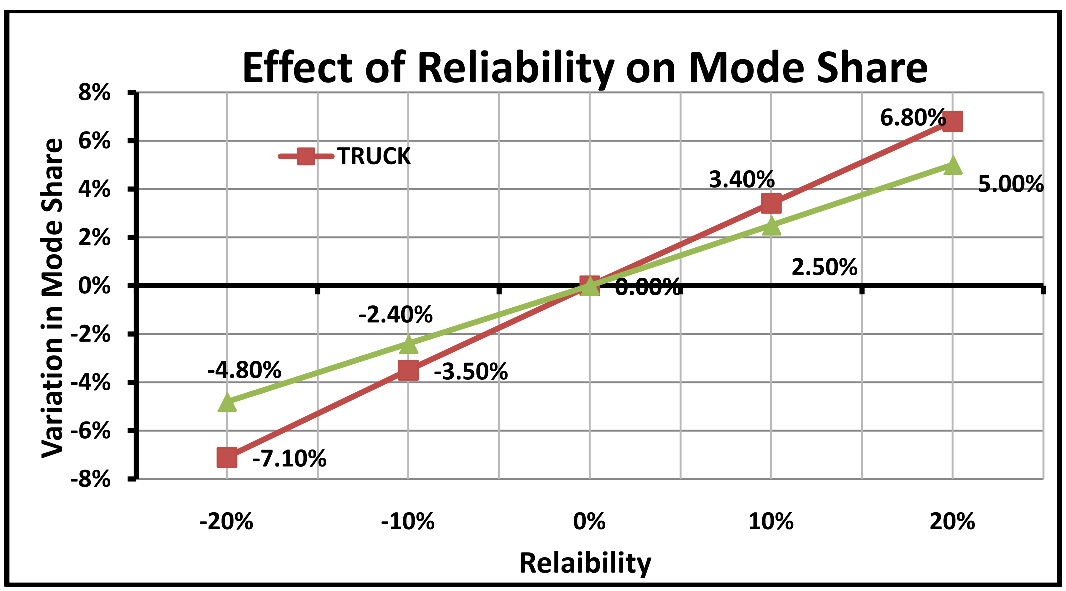


Figure 7.9 Elasticity of mode share with variation in reliability

7.3.3.5 Results of elasticity analysis

From the above analysis, it can be seen that the transportation time is more elastic than the transportation cost. A 10% increase in truck time led to a reduction of 4.7% truck share while 10% increase in transportation cost of truck led to 3.9% reduction in mode share. Similarly, 10% increase in transportation time of train led to 10.9% decrease in its mode share where as a 10% increase in transportation cost of train led to a reduction 9% mode share. Also, while comparing modes, freight train is more sensitive to cost and time variation than truck transport. The business as usual (BAU) scenario represents the case if the dry port and freight rail service are not developed, and there would be no modal shift and truck would continue to carry 100% of international freight. The base case (SC-1) represents the mode share estimated based on cost and time of each modes determined by the pilot study. The following Table 7.10 summarizes the results of elasticity analysis.

Table 7.10 Mode share from elasticity analysis

		Mode share	
Scenario	**Scenario detail**	**Truck**	**Train**
BAU	Business as usual	100%	0%
SC-1	Base case	56.8%	43.2%
SC-2	10% increase in cost of truck transport	52.8%	47.2%
SC-3	10% decrease in cost of truck transport	60.7%	39.3%
SC-4	10% increase in cost of train transport	65.8%	34.2%
SC-5	10% decrease in cost of train transport	47.4%	52.6%
SC-6	10% increase in time of truck transport	52.1%	47.9%
SC-7	10% decrease in time of truck transport	61.4%	38.6%
SC-8	10% increase in time of train transport	67.7%	32.3%
SC-9	10% decrease in time of train transport	45.2%	54.8%

7.4 Assessment of CO_2 emissions from operation

The types of goods vehicles and train used in Laos are similar to that of Thailand. Further as the majority of Thanalaeng- Laem Chabang route is in Thailand, the emissions factor applied in Thailand are used for assessment of emissions. The emission factors are derived based on the information provided by the Ministry Transport, Thailand (Chamroon 2011). Using the factor of 2328 gm CO_2 emissions/litre, the derived emission factor for freight train and truck is shown in Table 7.11.

Table 7.11 Emission factors

Mode	Emission factors
Truck	93.12 gm /ton-km
Freight Train	27.4 gm /ton-km

The above emission factors are comparable to similar factors in Europe (92 gm /ton-km for Heavy Duty Vehicle and 22.8 gm /ton-km for rail) and Canada (114 gm /ton-km for truck and 17.85 gm /ton-km for train). ADB’s TEEMP project uses 80 grams/ton-km for roads and 25 gm/ton-km for trains (ADB 2011). For the purpose of comparison the emission factor for commercial truck in Japan is 150 gm/ton-km and that for freight train is 20 g/ton-km. This is due to use of more energy efficient electric train and the higher factor for trucks could be due to use of smaller trucks for delivery and low load factor.

Table 7.12 shows the forecast of freight volume at Thanalaeng dry port (JICA 2011). The freight demands are estimated based on 2009 values, the total import and export through Vientiane is 1.026 million tons. The estimates are based on the annual GDP growth of 8.0% during 2011 to 2020 and population growth of 1.7%. Applying the same principle, freight volumes for 2011 and 2020 are estimated as shown in Table 7.12. It was also estimated that 32% of general cargo would be transported in container by 2025.

Table 7.12 Forecasted freight demand at Thanalaeng

Year	Cargo Demand, MT
2009	212680
2011	248070
2015	426500
2020	919780
2025	1413060

Utilizing the above emission factors and mode share scenarios outlined in Table 7.23, the assessment of CO_2 emissions for the estimated international traffic to/from Thanalaeng is done. While estimating the emissions as the total trade with Thailand is 70% and the transportation of import and export is considered to Bangkok and other 30% of international transport would originate/terminate in Laem Chabang port. The length of Thanalaeng-Nongkhai railway line is 3.5 Km, Nongkhai- Bangkok is 624 Km and Bangkok-Laem Chabang line is 140 km (SRT 2011)[18]. In case of road, the length of Thanalaeng-Bangkok is 622 km and Thanalaeng -Laem Chabang is 771 Km (ESCAP 2008)[19]. Table 7.13 shows the road and rail distance used for analysis

Table 7.13 Road and rail distance from port to dry port

S. No.	Origin/Destination	Road	Railway
1	Thanalaeng – Bangkok	622 km	628 km
2	Thanalaeng – Laem Chabang	771 km	768 km

Table 7.14 shows the assessment of CO_2 emissions for various scenarios shown in Table 7.10.

[18] Railway Network, State Railway of Thailand, www.railway.co.th/English/network.asp (accessed on 15 October 2011)
[19] Asian Highway Database, 2008, ESCAP

Table 7.14 Assessment of CO_2 emissions (in tons)

Scenarios	CO_2 Emission 2015 (MT)	Reduction in emissions compared to BAU
BAU	26478	0
SC-1 (Base)	18406	30.5%
SC-2	17658	33.3%
SC-3	19134	27.7%
SC-4	20087	24.1%
SC-5	16649	37.1%
SC-6	17527	33.8%
SC-7	19265	27.2%
SC-8	20442	22.8%
SC-9	16238	38.7%

The above assessment shows that 43.2% fright mode shift to railways (base case) resulted in 30.5% less CO_2 emissions than business as usual (BAU) scenario[20], while scenario 9 with rail mode share of 54.8% freight mode shift to railways resulted in 38.7% CO_2 emissions reduction than BAU. Scenario 8 results in 22.8% CO_2 emission reduction which is least among the evaluated scenario that corresponds to a mode shift of 32.3% to railways.

The above assessment seems reasonable and valid based on the outcome similar research conducted earlier. For example, the energy saving from the use of intermodal transport was estimated as 25% in Thailand (Hanaoka et al. 2011), use of freight train for transport from a seaport to a port in Sweden resulted in 25% emission savings (Roso 2007), Liao et al. (2010) showed a 60% savings from use of intermodal transport (truck and coastal shipping) instead of truck only transport in Taiwan and Patterson et al. (2008) demonstrated that a reduction of freight CO_2 emissions by 16% (on average) 16% and 50% (at best case scenario) was possible by use of intermodal transport services in the Quebec City-Windsor Corridor.

The emissions reduction depends on the emission factors used, freight volume, distance and mode share. The survey of emission factors of freight train show variation from 21 g/ton-km to 63 g/ton-km for freight train. The emission factor for diesel train in Finland is 22g/ton-km and for US is 63 g/ton-km (ADB 2011). Using the emission factors of 103.6 g/ton-km for truck and 30.5 g/ton-km for train[21], the estimated CO_2 emissions is 29,458 tons and 20,479 tons respectively for BAU and base case for 2015. Even though slight optimistic default emissions factors 80 g/ton-km for truck and 25 g/ton-km for heavy train (ADB 2011) gives 22,748 tons and 15,992 tons respectively for BAU and base case for 2015. The use of different factors give different absolute value of emissions but both give same 30% emission reduction compared to

[20] Assessment of emissions using the generic model outlined in Table 7.20 and omitting the insignificant alternate specific constant for truck show a 29.1% CO_2 emission reduction compared to BAU.
[21] Derived using the activity data and the carbon content of diesel (2590 gm/l) provided by the Petroleum Authority of Thailand (PTT).

the base case. Thus in a given scenario the emission reduction largely depends on the potential mode shift to railways.

7.5 Emission assessment for other dry ports

An assessment and comparison of emissions that would be generated from other dry ports is also done. Table 7.15 shows the freight demand for Thakhek, Savannakhet and Phakse (JICA 2011). The volume for Thakhek for 2015 is estimated considering similar growth figure as in Savannakhet.

Table 7.15 Freight demand and distance

	Freight volume (tons)		Distance to	
Dry port	**2015**	**2025**	**Bangkok**	**Laem Chabang**
Thakhek	19,000	79,000	681 Km	846 Km
Savannakhet	36,000	151,000	608 Km	773 Km
Phakse	106,400	296,000	689 Km	854 Km

Source: JICA, 2011

The emission is estimated based on the emission factors considering the same factor as Thanalaeng that 70% of cargo would be bilateral trade and 30% would be international trade. Table 7.16 shows the comparison CO_2 emissions for all dry ports considering the same amount of mode shift with share of truck 57% and train as 43%. It can be seen from the figure that the emissions would be higher from the Thanalaeng because of the freight volume. Interestingly, the reduction share does not depend on the distance and freight volume. It depends on mode share and the emission factors used.

Table 7.16 Emissions from other dry ports

	CO2, Tons (2015)		Emission
Dry ports	**BAU**	**Mode shift**	**Reduction**
Thakhek	1,292	898	30.5%
Savannakhet	2,204	1,532	30.5%
Phakse	7,317	5,086	30.5%
Thanalaeng	26,478	18,406	30.5%

7.6 Life cycle assessment of construction

The construction of dry port at Thanalaeng is essential to start the freight train service. The life cycle assessment (LCA) of CO_2 emissions from the construction of the dry port is assessed. It is very difficult to find construction emission factors in the Asian context. The emission factors provided by the Swiss Centre for Life Cycle Inventories (Ecoinvent Centre, 2007) are used for estimation of the life cycle emissions.

The estimated quantities for the development of dry ports are taken from the feasibility study (JICA, 2011). For the estimation of earthworks, the average depth of ground preparation and slope protection work is taken as 30 cm. The thickness of various sizes of concrete drain and cover is taken as 10 cm, and height of the administrative office complex is taken as 4 m. The assessment does not include emission for construction of water supply works, electricity lines, signals and communication equipments within the dry ports, as the construction cost of these items were not significant and also it was difficult to estimate the emission factors for these items. The road pavement inside the dry port is considered to be of cement concrete similar to the pavement of the container yard.

Table 7.17 shows the main construction activities, CO_2 emissions factor and life cycle emissions from the construction of dry port at Thanalaeng.

Table 7.17 Life cycle CO_2 assessment of construction of Thanalaeng dry port

S. No	Construction item	Quantity	Unit	CO_2 emission/unit	CO_2 emissions, (kg)
1	Earthwork				
	Ground preparation work	120,000	m^3		
	Excavation	1,278,266	m^3		
	Filling	10,624	m^3		
	Slope protection	1,500	m^3		
	Total earthworks	1,410,390	m^3	0.515	726,351
2	Cement concrete in container yard, road and drains	44,560	m^3	255.4	11,380,624
3	Building with steel structure for warehouse, container freight station, truck terminal, maintenance shop and parking	30,810	m^2	286.9	8,839,389
4	Concrete buildings for administrative office complex and security gate	4,160	m^2	46.575	193,775
5	Railway siding inside the dry port	64,000	m	39.7	2,540,800
	Total				23,680,916

The life cycle CO_2 emission of the dry port is estimated at 23,681 tons. For the base case scenario the emissions reduction was 8072 tons in 2015, considering the 7% growth (similar to GDP) of freight volume and same mode share the emissions savings for 2016 and 2017 would be 8637 tons and 9242 tons, respectively. The resulting emission reduction in 3 years would be 25,951 tons. This demonstrates that the life cycle emissions from the construction of the dry port would be offset in three years from the start of operation of the dry port and freight train. It should be noted however that the above estimate does not cover the emissions from operation of the dry port.

7.7 Results and discussion

The modules 3 and 4 of the integrated methodology were applied to estimate the mode choice model between truck and train, mode shift and resulting CO_2 emissions. In order to estimate the model time, cost and reliability of freight transport were used as model parameters. A robust model with high level of significant parameters was developed based on the feedback received from freight forwarders in Laos and Thailand. The model result showed a modal shift of 43% to railways from road at base case. The resulting CO_2 emissions was calculated using bottom-up approach, the result showed that 30% CO_2 emission reduction.

The construction of dry port at Thanalaeng, priority location selected by location analysis, is the minimum requirement to facilitate and initiate rail freight transport and mode shift. The dry port facility would also need infrastructure and equipment to handle containers and cargoes transported by railways. These would be reach stackers, gantry cranes, stock yard, covered cargo areas, railway siding and vehicle parking, office space including customs processing. As the railway link is already complete, the cost involved is only for the development of dry ports. While, in case of other potential location, in addition to construction of dry ports- railway lines and connectivity has to be improved. The life cycle assessment showed that the CO_2 emissions from the construction of dry ports would be compensated from the reduction of emissions from the mode shift within three years of the start of operation of the dry port.

This demonstrates the role of dry ports in contributing to climate change mitigation by facilitating a mode shift and reducing emissions. Also, the development of dry ports in inland secure area can contribute to adaptation. Thus, dry port development in inland area can have positive environmental benefits as it contributes to mitigation as well as adaptation.

Elasticity analysis of allowed to evaluate the effect of variation of attributes considered on mode share. This analysis is very useful in real case scenarios as it allows the stakeholders and decision makers to see the tradeoff between cost and mode shift as well as time and mode shift. This would enable the decision makers to consider measures and ways to influence the attributes. For example if the time is likely to increase and cause the mode share to decrease, policy makers may consider ways to reduce transportation time such as making border crossing efficient and increasing efficiency of railway operation. If the cost is a cause of concern of reduced mode share, then it could be left to the market to compete or in some cases possible ways could be providing subsidies to railways.

The analysis is based on the stated preference survey of freight forwarders in Laos and Thailand. One of problem encountered during the interview survey was bias of respondents to a particular mode, in this case truck or train. Even though they were asked to consider and evaluate values of attributes prior to selecting a mode in a question, about 16 respondents chose only one mode. Therefore, due to their bias those were not included in the analysis. Similar experience as in AHP survey was also observed, many potential respondents promised to send feedback through email but they did not.

The integrated methodology can demonstrate importance of environmental consideration and its emission reduction potential in addition to their commonly understood roles to facilitate logistics services. As modal shift is recognized as an approved methodology for UNFCCC, if emission reduction potential of a project can be demonstrated utilizing the integrated methodology, this could qualify as a project for consideration by the Global Environment Facility (GEF). One of the criteria to qualify is to demonstrate emission reduction as a result of implementing policy and a project. The result shows the overall usefulness of the integrated methodology, which can provide stakeholders and policy maker's information concerning the various options, modes, emissions, elasticity of variation which would be useful in evaluating policy options to make informed decisions.

7.8 Chapter summary

This chapter applied modules 3 and 4 of the integrated methodology. The stated preference data were analyzed for parameter estimation of the utility functions for choosing truck and train mode. All together six mode specific parameters were estimated corresponding to time, cost and delay variables. Using the mode specific utility function, mode share of each mode was estimated using the logit model which resulted in 57% share to truck and 43% to train. Sensitivity analysis was conducted to evaluate various scenarios resulting from different attributes values. The corresponding modal share were estimated and used for assessment of CO_2 emissions. Based on the scenarios being considered, the resulting reduction in CO_2 emission varied from 24% to 39% compared to business as usual.

CHAPTER 8

CONCLUSIONS

8.1 Introduction

The current research attempted to explore adaptation and mitigation aspect of the sustainable transport development. The research proposed and applied an integrated methodology to assess impacts of climate change on transport and to evaluate potential mode shift and emission reduction through dry port development. This chapter outlines the findings, results and discussions and conclusions of the research and overall discussion on the use of the integrated methodology. It also lists some areas for extension of current methodology and research that can be further explored in future research.

8.2 Summary of the findings

The primary objective of the research is to assess the impacts of climate change on transport in Asia and study mitigation potential of the dry ports. Within this main objective the research focused around three objectives of the research as outlined in section 1.3 which included assessment of climate change impacts, analysis of dry ports location to promote intermodal transport and assessment of resulting modal shift and emissions. The key summary of the findings are outlined in the following paragraphs.

8.2.1 Impacts of climate change on transport and adaptation

The assessment was done utilizing module 1 of the integrated methodology. Climate events such as rainfall, rise in temperature, rise in sea levels and storm surges have substantial impacts on transport infrastructure and operations. This research highlighted the importance of planning and designing transport infrastructure considering the likely impacts of climate change as well as life cycle costs. The process of reviewing designing standards and practices could be relatively easier in Asia. Climate change impact assessment guidelines would help to systematically evaluate the impacts, awareness and advocacy programme would help to initiate, plan and implement adaptation strategies. As impacts are widespread, coordination at national, regional and local are essential for implementation of strategies.

The variation of intensity of climate events and degree of impacts in different Asian subregions indicated the need to adopt different strategies and policies to develop sustainable transport development. Adaptation measures in transport are costly and it takes time to mainstream the process. The increased level of awareness and coordination among all Asian stakeholders would be essential to develop sustainable transport.

A conceptual framework of the adaptation process is proposed. The strategic environmental assessment (SEA) at policy, programme and planning level and EIA at the project level would help to implement adaptation strategies and measures. The development of dry ports at secure inland locations away from vulnerable coastal areas safeguards it from risk of damage from rising sea level or storms and thus contributes to the adaptation process. The adaption framework was applied to the development of dry port.

8.2.2 Development dry ports and location analysis

The case studies of dry ports revealed their roles in promoting modal shift and environmental benefits due to reduction in road congestion and emissions due to modal shift. Countries are taking various measures and different approaches for development and operation of dry ports. While for infrastructure development all forms of ownerships such as public, private and public-private partnerships were evident. The operation of dry ports was mostly handled by the private sector and in some cases by subsidiary of the government. Some of the constraints to improve intermodal transport were lack of sufficient locomotives and wagons to increase frequency of container block train services from dry port to/from seaports and the need to improve efficiency of services.

The location of proposed dry ports in Laos was analyzed utilizing module 2 of the integrated methodology that included and AHP and combined AHP-goal Programming. The location analysis ranked Thanalaeng, which is close to Vientiane, with highest priority. Savannakhet was ranked 2nd, Thakhek the 3rd and Phakse received least priority. The combined AHP-Goal Programming analysis selected Thanalaeng, Savannakhet and Thakhek. These results are consistent with the view of the freight forwarders and government officials. However, some difference in weights of each criteria and sub-criteria were noted among government decision makers and private sector freight forwarders.

The development of dry port and logistics infrastructure is not sufficient in itself; further additional efforts are required to operate these facilities. More importantly reduction of documents to be handled in dealing with export and import, implementation single window system thus eliminating double inspection of cargoes at the border as well and at the dry ports are some of the policy issues that need to be considered. There is no “one fits for all policies” these should be implemented by taking a step by step approach. As the railway connectivity to Thailand has now been completed, the start of regular freight train between Thailand and Laos would help to improve international freight transport and to reduce environmental burden to some extent. By effectively using the dry ports as consolidation and distribution centers number of less-than-truck trips could also be reduced. These facilities would also help to improve transit transport through Laos and transforming it as a “land-linked” country in South-East Asia.

8.2.3 Freight modal shift and CO_2 emissions

Utilizing the outcome of the location analysis module 2, the potential modal shift was assessed by utilizing module 3 of the integrated methodology. Initially based on the feedback received from freight forwarders in Laos and Thailand on the stated Preference survey – model parameters were estimated for the utility functions. The outcome of discrete choice analysis showed very significant output and robust utility model. Using the utility function and logit model, the mode share estimated was 57% to road and 43% to railways at the base case. Elasticity analysis was conducted to evaluate variation in modal shift due to change in total transportation cost, transportation time and combination of both. The results showed that a 10% increase in transport costs truck would reduce its mode share by 3.9%; while 10% increase in transport cost of train would reduce share of train by 9%. While, a 10% decrease in transportation time of truck would lead to an increase of 4.6% mode share. Similarly, 10% reduction in transportation time by train would result in 11.6% increase in its mode share. Module 4 of the integrated methodology was used to analyze the CO_2 emissions from potential modal shift. In base case scenario the reduction in CO_2 emissions was estimated as 30% for 2015 compared to business-as-usual case. The life cycle assessment also showed that the CO_2 emissions from the construction of the dry port can be offset within three years of start of operation.

8.3 Results and discussion

The integrated methodology allowed not only selecting and prioritizing dry ports based on the transport cost and transportation time but also considering subjective criteria that are important to the policy makers such as environmental benefits, regional economic development. The analysis provides policy makers added information on the perception of the stakeholders in addition to the cost benefit analysis for project appraisals. Further, the goal programming utilized the optimization techniques of the evaluation criteria used. It allowed to define and include user's defined goals and targets of the criteria such as minimization of costs, time and environmental impacts and maximization of intermodal transport linkages and regional economic development.

There is much argument about whether to encourage centralized or decentralized freight distribution system. This helps to visualize how much these important goals are under or over achieved. This again considered input from government policy makers; freight forwarders thus can help decision makers in making rational decisions while considering the feedback of stakeholders. Badri (1999) used combined AHP-GP in location allocation problems. The methodology is further enhanced and integrated by combining stated preference techniques for mode choice and emission assessment.

There has been much argument on the role of dry ports in promoting modal shift. The stated preference survey and analysis allowed to assess the modal shift opportunities. Further, the life cycle assessment as well as life cycle costs to see how the carbon emissions can be offset would be interesting to see as well as well as the cost involved to develop infrastructure to create modal shift opportunities.

The railway connection to Laos has already been developed, now the efforts and investment are required for the construction of the dry port at Thanalaeng with cargo and container handling facilities. This is essential to start the rail freight operations. The overall cost involved to start operation would also be less compared to other potential dry ports as only dry port construction is needed at Thanalaeng. While other locations need construction of railway links in addition to dry port. Owing to the fact that passenger train between Thailand and Laos is already in operation, there is high possibility to start the freight train service after completion of the dry port in near future.

The integrated methodology also assessed CO_2 emission and enabled to compare with base case scenario. Elasticity analysis helped to study the effects of cost and time variation on modal shift and emissions.

Further there is strong logical linkage between analytical modules and thus integrates well with each other. The output of the preceding modules feed into the subsequent modules as an input. The application of the integrated methodology in ‘real case’ situation in the development of dry ports in Laos and international freight transport and robust results and outcome shows its feasibility for application in other cases. It could be further enhance through integrating life cycle assessment as well as cost analysis.

Four set of primary data were collected for the research through (i) adaptation survey; (ii) AHP survey; (iii) SP survey; and (iv) visits to dry ports for collection of case studies. There has been mixed experience during primary data collection. One of the difficulties during the research was problem faced during data collection. Despite having good contacts with transport policy makers, in Asia, Freight forwarders in Laos and Thailand and government decision makers in Laos, the data collection exercise took much time and efforts than originally envisaged. While the data collection interview survey, visit to the site were well organized with local coordination, the level of response from freight forwarders and private sector was not encouraging. One of the reasons was that the AHP questionnaire was long and it took about 20-30 minutes to complete it, so they asked to leave the questionnaire during the meeting with a promise to send reply by email– but in many cases they did not responded. The lesson is to get feedback during direct interview possibly through setting another interview date and extending the time allocated for the interviews. The flooding situation in Thailand during October-November 2011 also hampered mobility and travel to freight forwarders offices for interview, as many were located in the areas affected by floods and many potential respondents have to be relocated due to the floods.

8.4 Conclusions

For the development of sustainable transport, the research identified the need to consider climate change impact while planning and designing transport infrastructure. The need of strategic climate change and environmental impact assessment (SEA and EIA) guidelines and the need to strengthen capacity of transport professionals and policy makers in Asia to consider climate change impact emerged as important considerations.

The research proposed integrated methodology, and applied in real case situation. The outputs were validated through comparisons of results from other studies and judgments. The application of methodology would be useful for the decision makers and assist in making informed and rational decision making by comparing various outcomes of the analysis of alternatives.

The research extended the methodology used by Badri (1999) and integrated to include modal shift and emission assessment analysis and applied in transport sector. Also the methodology incorporated the assessment of climate change impacts and covered both adaptation and mitigation issues for sustainable transport development.

Thanalaeng dry port in Laos received high priority among the policy makers as well as freight forwarders compared to other dry port location being considered. The analysis of stated preference survey result showed a modal shift of 43% to railway from road if freight train service would be available along Laem Chabang-Thanalaeng route after construction of the Thanalaeng dry port. This would result in 30% CO_2 emission reduction from modal shift. The life cycle assessment indicated that the construction emissions can be offset within three years of start of dry port operation. The application of integrated methodology to demonstrate emission reduction potential of dry port could be useful in formulating policies and project.

Application of the integrated methodology and elasticity analysis can provide decision makers useful information to support rational decision making to initiate adaptation measures to safeguard transport infrastructure develop sustainable transport, develop dry ports to promote modal shift.

8.5 Further research

Availability of limited literatures on transport and climate change studies in Asia indicates further research needs in area of country specific assessment and quantification of impacts and adaptation strategies for developing sustainable transport infrastructure.

The mode choice analysis only considered two modes road and rail. The research can be extended to third mode as intermodal transport. Further, the mode choice model can be improved by adding more attributes of freight and shipment such as frequency of freight trains, type and value of commodity to be transported.

In terms of emission assessment, there is scope to further extend the research to analyze process based life cycle assessment as well as life cycle costing approach to infrastructure investment to promote modal shift. The correlation between investment in dry ports and railways, and resulting modal shift would be an interesting area to explore.

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Appendix I- Review of evaluation criteria, sub-criteria for location analysis

Reference	Criteria	Sub criteria	Goal and alternatives
1. Kahraman et al. (2003)	(i) Environmental regulation (ii) Host community (iii) Competitive advantage (iv) Political risk		Select best location for a factory: • Istanbul, • Ankara • Izmir.
2. Guneri et al. (2009)	(i) Labour	• Labour quality, • Labour cost, • Labour supply	Select shipyard location using ANP among four alternatives: • Samsun • Yalova • Izmir • Yumurtahk
	(ii) Government	• Incentive	
	(iv) Environmental	• Geological • Climate • Transportation • Demographic structure	
	(iv) Regional economy	• Economic • Industrial situation	
	(v) Physical condition	• Land cost • Construction cost • Enlargement of shipyard • Protection from sea condition	
	(vi) Raw material		
3. Onut et al. (2010)	(i) Port Location	• Proximity to import/export area • Feeder or hub port • Main navigation route	Develop MCDA port selection model, alternatives are: • Marport • Kumport • Mardas • Aktas • Gemport • Borusan • TCDD Haydarpasa
	(ii) Hinterland economy	• Volume of import/export containers, • Transshipment containers • Frequency of ship calls	
	(iii) Physical features of port	• Infrastructure • Port facility and equipment • Intermodal links	
	(iv) Port efficiency	• Container handling efficiency • Port berthing time length • Container yard efficiency • Custom efficiency	
	(v) Costs	• Port charge • Inland transshipment freight rates	
	(vi) Others	• Port future development plan,	

		• Personal relations, information service at port, • Port security • Good reputation related to damage delays	
4. Lv and Li (2009)	(i) Development status	• Development of the city • Development level of nearby cities • Potential of the city development	Selection of location of a dry port for Tianjin port. The options considered were: • Yinchuan • Datong • Shijiazhuang • Handan.
	(ii) Traffic convenience	• Traffic between dry ports and sea port • Traffic radiation area of the city • Traffic capacity	
	(iii) Labour resources and technology	• University and colleges • Capacity of local labour market • Status of high tech industry and labour	
	(iv) costs	• Transport costs • Local labour wage level • Use of land resources • Environment protection	
5. Wang and Wei (2008)	(i) Natural environment	• Weather • Geological • Hydrological • terrain	Location of a dry port for Tianjin port the options were: • Baoding • Dezhou • Huhhehoate • Haozhou
	(ii) Operating Environment	• Labour condition • Characteristics of goods • Service level • Customer condition	
	(iii) Infrastructure status	• Traffic • State of public facilities • Information infrastructure	
	(iv) Costs	• Transport costs, • Local labour wage level • Use of land resources • Environment protection	
6. Kunadhamraks and Hanaoka (2009)	(i) Logistic costs	• Transport cost • Handling cost • Holding cost;	Evaluate logistic performance of intermodal transport.
	(ii) Service quality	• Travel time • Information system • Flexibility;	
	(iii) Reliability	• Frequency of disruption	

		• Frequency of delay • Duration of disruption • Duration of delay	
	(iv) Security	• Frequency of freight damage • Severity of freight damage	
7.Lee (1998)	(i) Travel time saving		Select best railway network development among three alternatives: • Alternative 1 • Alternative 2 • Alternative 3 Also considered three groups of stakeholders: • Supplier • User • Community
	(ii) Comfort and safety		
	(iii) Project cost		
	(iv) Urban travel cost		
	(v) Socio economic benefits	• Regional development • Severance effect • House replacement	
	(vi) Environmental effects	• Noise • Ecology • Visual Intrusion • Cultural assets	
8.Ozdagoglu and Ozdagoglu (2007)	(i) Technical attributes	• Proficiency • Carefulness • Harmony with the team working	Employee selection criteria
	(ii) Behavioral attributes	• Devotion • Cleanliness • Morality	
	(iii) Other factors	• Not being the criminal record • Residing in the close environment • Being a reference	
9. Wu et al. (2005) Building and Environment	(i) Factor condition	• Capital • Labour • Land	Hospital location selection alternatives: • Taichung City • Taiping • Dali (Taichung ranked 1st)
	(ii) Demand condition	• Population number • Population density • Population age distribution	
	(iii) Firm strategy, structure and rivalry	• Management objectives • Rank of competitive hospitals • Policymakers attitude	
	(iv) Related and supporting industries	• Healthcare sector • Medicine and pharmaceutical • Hospital administration	
	(v) Government	• Regulation and standards • Efforts to promote medical	

		network • Hospital assessment	
	(v) Chance	• Change in market demand • Cost fluctuations • Change in financial market and exchange rate	
10. Yelda and Shrestha (2007), Urban transport options in New Delhi	(i) Energy (ii) Environment (iii) Cost (iv) Technology (v) Adaptability (vi) Barrier		Options: • 4S-2 Wheelers • CNG Car • CNG Bus
11. Yang et al. (2008), Facility location	(i) Market attraction	• Passerby flow • Security issue • Clustered market • Public transit • competition	
	(ii) Consumer characteristics	• Consumer population • Consumer density • Disposable income • Purchasing power • Brand loyalty	
	(iii) Location qualification	• Rent • Flexibility of lease term • Shop size • Employee recruiting • Expected revenue • Visibility of the shop • Accessibility of the shop • Synergy between each branch	
12. Macharis (2001), Location of barge terminals	(i) Increase of users benefits	• Reduction in transport cost • Reduction in transport time • Reliability of connection • Time variation between collection and delivery of goods • Integration with other modes • Extension of services	
	(ii) Increasing benefits of the investors/operators	• Maximizing the actual value • Maximizing the possibility to extend • Maximizing the existing infrastructure	

	(iii) Increasing benefits of the community	• Optimization of the efficiency of network • Minimization of the road congestion • Max economic benefits • Minimization of effect on the neighbor • Minimization of pollution levels	
13. Ugboma and Ugboma (2006), Nigerian Ports-Maritime Eco and Logistics	(i) Efficiency (ii) Frequency of ships visits (iii) Adequate Infrastructure (iv) Location (v) Port charges (vi) Port reputation for cargo damages (vii) Quick response to Port user needs		Service characteristic considered by shippers on port selection alternative Ports: • Lagos • Tincan • Harcourt • Ro-Ro Port
14. Tuzkaya et al. (2008), Transport mode selection between Turkey and Germany	(i) Cost	• Handling costs • Defective freight costs • ICT cost • Transportation cost	Alternatives: • Rail • Road • Sea
	(ii) Flexibility	• Handling the unexpected changes • Capacity flexibility • Route flexibility	
	(iii) Product characteristics	• Weight • Packaging features • Volume • Stacking-up requirements • Transportation features • Product life • Product value	
	(iv) Reliability	• Late arrivals • Stable arrivals • Reliability on schedule	
	(v) Risks (vi) Safety problems	• Storage risk • Political risks • Social risks • Environmental risks • Burglary • Accident	

		• Diversity of accident cause • Damaged product	
	(vii) Speed (viii) Traceability	• Transshipment time • Transportation speed • Transportation distance • Transportation time • Freight and vehicle • Container • All other factors	
15. Reza et al. (2011), Flooring, LCA and AHP	(i) Environmental impacts	• Resources depletion • Wastes and emissions • Waste and management • Climate change • Environmental risk • Embodied energy • Energy loss	Options flooring: • Clay blocks • Concrete blocks • Expanded polystyrene (EPS)blocks
	(ii) Economic impacts	• Material cost • Construction cost • Occupation and maintenance cost	
	(iii) Socio-political impacts	• Social acceptance • Vulnerability of area • Building weights	
16. Brozova and Zika (2010), EIA of Transport	(i) Water and Air	• Local air quality • Regional air quality • Quality of water • Ozone depletion • Climate changes	
	(ii) Senses and waste/energy	• Noise and vibration • Waste • Light pollution • Non-renewable resource use	
	(iii) Countryside	• Preserved nature areas • Losses of biodiversity • Cultural and technical heritage • Land take	
	(iv) Technology and safety	• Technological hazards • Safety of transport users and pedestrians	
17. Berrittella et	(i) Less carbon content fuel		Six policy

al. (2007), AHP to evaluate transport policies to reduce climate change impacts	(ii) Vehicle efficiency (iii) Increase public and multi-modal transport share (iv) Better mobility management Option 3 evaluated as the highest ranking- environmentally friendly mode		options: 1. Agreement to improve vehicle efficiency 2.Incentives- car fleet renewal 3. Promote environmentally friendly mode 4.Integration of transportation planning and land use 5. Better infrastructure 6. ITS
18. Mohajeri (2010) Railway site selection in Iran	(i) Rail related	• Feasibility of connecting new and old lines • Creating new lines • Using existing equipments • Access to existing rail network • Communication with other stations • Geometric limitation • Coordination of train movement and maneuvers	Four options: • Move to Salaam • Renovation of existing • Redevelopment of existing and establishing a satellite station • Satellite station next to underground station
	(ii) Passenger Services	• Services to passenger • Access to city transport system • Access to intercity transport system • Proximity to station • Reduction in journey time • Easy access to urban facilities	
	(iii) Architecture and urbanism	• Harmony • Coordination with dev plans • Effective land possession • Harmony with city image • Harmony with environment • Potential for future development • Easy access • Coordination with defense	

	(iv) Economics	• Return on investment • Opportunity cost on existing jobs • Creating added value to the region • Decrease in passenger costs • Useful land uses	
19. Park et al. (2010), Competitiveness of air cargo carriers	(i) Promptness	• Quick pick-up • Quick delivery • Network • Quick response	Alternatives: • DHL • FDX • UPS • TNT • EMS DHL ranked 1st
	(ii) Accuracy	• On time pick-up • Pick-up service area • On-time delivery • Accurate delivery	
	(iii) Safety	• Handling • Compensation • Problem solving • Information • Facility • Damage and loss	
	(iv) Convenience	• Service area • Branch • Booking • Tracing • Schedule	
	(vi) Economic efficiency	• Moderate price • Variety rate • Reasonable price • Rate policy	
	(vi) Dependability	• Packing condition • Image • Customs clearance	

Appendix II: Adaptation Questionnaire

Survey of Climate Change Impacts on Transport and Adaptation in Asia
(Please return the completed questionnaire by 20 July 2009)

The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report make following predictions of climate variability in Asia:

i. the increase in temperature will be 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.

The transportation system such as roads, railways, air transport and water transport will be affected by these climate events. There are compelling arguments that transport infrastructure should be able to withstand the impacts of climate events such as excessive rains, flooding, rise in sea level, rise in temperature, storm surges, frequent snowing and ice melting triggered by the climate change.

In this background, a research on studying the Impacts of Climate Change on Transport and Adaptation in Asia is being undertaken at the Tokyo Institute of Technology. This survey is being conducted to assess the existing state of environment and climate change policies, guidelines, implementation, coordination and institutional set up in Asian countries.

Your support in timely completion of the survey questionnaire and contribution to the study will be highly appreciated. The finding of the study will help plan and develop sustainable transport policies/programmes for Asia that could be implemented in member countries.

Please provide **your personal view** while answering questions even some questions may refer to government programmes, policy and implementation. Your response will be treated in strict confidence. All responses will be aggregated and analyzed.

Please return the completed questionnaire **to Madan B. Regmi**:

- **on or before 20 July 2009**
- **by email mbregmi@gmail.com**
- **or by FAX: +81-3-5734-3468**

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If you have any questions related to the questionnaire please contact Madan B. Regmi, by email <**mbregmi@gmail.com**> **or** Tel/Fax: +81-3--5734-3772.

Section A: Awareness of climate change and adaption measures in transport sector

1. How do you rate the general level of awareness of **policy makers and transport officials** about environment, climate change and **adaptation**[22] and in your country?

☐ VERY HIGH ☐ HIGH ☐ ADEQUATE ☐ LOW ☐ VERY LOW

2. How do you rate the general level of awareness of **general public** about environment, climate change and adaptation in your country?

☐ VERY HIGH ☐ HIGH ☐ ADEQUATE ☐ LOW ☐ VERY LOW

3. Please indicate in the scale given below to which extend you agree to the following about climate change and impact on transport **(1-Strongly Disagree, 2-Disagree, 3-Neutral, 4-Agree, 5-Strongly Agree)**

The climate change is a cause of concern	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Climate events will affect transport and operation	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Coastal infrastructure are vulnerable to climate change	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Bridges are prone to damage	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Possibility of overflow of side and cross drains	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Heavy snow will disrupt transport and traffic	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Pavements deterioration will be faster by high temperature	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
More traffic disruption due to landslides	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Poor driving condition due to fog, storm	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Strong winds may damage road signs	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Our region will not be much affected by climate change	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
It will be costly to repair infrastructure	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Design standards and criteria may need to be revised	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
It will be costly to adopt higher design standards	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Section B. Information on emergency preparedness

4. Please indicate occurrence significant climate events (such as heavy rain, flooding, heavy snow, extreme temperature, wind storm etc.) within last 3 years in your country?

☐ YES ☐ NO

5. How do your rate the response from the relief and transport agencies to provide immediate help and relief (opening road, providing assistance etc.)?

[22] Adaptation refers to initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects.

☐ VERY FAST ☐ FAST ☐ NORMAL ☐ SLOW ☐ VERY SLOW

6. Do your think there is some scope of improvement in earlier emergency responses?

☐ YES ☐ NO

7. Any change in emergency preparedness policies, guidelines for reopening transport and in dealing with extreme climate events after those events?

☐ YES ☐ NO

8. Do you think coordination between the transport agencies and agencies responsible for emergency responses should be improved?

☐ YES ☐ NO

C. Design Standards and Practices:

9. To safeguard transport infrastructure from the impacts of heavy rains, floods, storms, heavy winds, sea level rise in your opinion which of the following options could be appropriate? **(You can check more than one)**

☐ Increase clearance above high flood level for bridges
☐ Design flood estimation, storm water taking account of predicted climate
☐ Consider increasing waterway and protection works to safeguard bridges
☐ Increase capacity of side drains
☐ Increase capacity and size of culverts, cross drainage
☐ Ensure effective drainage of surface water from pavement (camber, subsurface drains)
☐ Provide additional protection to coastal roads and railway
☐ Relocation of coastal road to higher place
☐ Raise height of embankment in flood plains
☐ Place sufficient warning and information signs
☐ Provide additional protection to ports and harbour
☐ Ensure efficient drainage in airports
☐ Provide adequate river protection works
☐ Provide adequate slope protection works
☐ Use stiffer bitumen in pavement (to safeguard from higher temperature)
☐ Use thick and strong pavement (more snow, icing, thawing)

10. Various structural components of transport infrastructure are designed for fit for purpose following existing standards, specifications and practice. Do you consider that design standards for critical and structural components of transport infrastructure should be reviewed or revised to withstand the impact of climate events?

☐ YES ☐ NO

11. Do you think it will be appropriate to revise the design flood estimation method and design

flow taking account of heavy precipitation, uncertainty and probability of occurrence of floods?

☐ YES ☐ NO

12. Are there existing clear guidelines to consider impacts of climate change while planning, designing and maintaining transport infrastructure?

☐ YES ☐ NO

13. Do you think that while planning and designing the vulnerable transport infrastructure the potential impacts of climate change should be considered?

☐ YES ☐ NO

14. Adopting higher design standards, criteria and guidelines may cost more initially. But in long run it may be an economical solution? Do you agree?

☐ YES ☐ NO

15. Provide any other suggestion how could we make transport infrastructure safe to withstand impacts of climate change?

____
____
____
____

D. Policy, guidelines, institution, coordination for implementation

16. Are there existing laws, and rules in your country to assess environmental and climate change impacts? (e. g. Environmental Impact Assessment (EIA), guidelines Climate Change Adaption and Mitigation)

☐ YES ☐ NO

17. If yes, please provide name of these, laws, rules, guidelines, policies decrees, and executive orders related to environment and climate change.

S. No.	Name	Year

[Please provide web link or electronic copy of the documents if available]

18. Which the followings reflects the need about the laws, rules, polices and guidelines on climate change and adaptation? (**Choose one**)

- ☐ Revision and extension of rules, polices and guidelines necessary
- ☐ New policies and guidelines to cover climate change and adaptation necessary
- ☐ No need to revise and introduce new polices and guidelines

19. If revision or extension of rules, guidelines are necessary, do you think extending the exiting EIA guidelines to include the climate change and adaption issues would be useful?

☐ YES ☐ NO

20. Are there climate change and adaptation **projects** in transport related being implemented in your country?

☐ YES ☐ NO

21. If yes, please provide brief project detail and sector (**road/railways/air/water transport**):

S. N.	Project Name, description	Sector	Year

22. Institutional arrangements: Is there an institution unit/division/department responsible for environment and climate change adaptation issue in: **(answer all questions from a to f)**

a. Central level high coordination body: ☐ YES ☐ NO

b. Ministry of Transport/Highway/Railway: ☐ YES ☐ NO

c. Road/Highway Department: ☐ YES ☐ NO

d. Railway organization: ☐ YES ☐ NO

e. Air Transport ☐ YES ☐ NO

f. Water Transport ☐ YES ☐ NO

23. How do you rate the coordination between above organizations transport/road/railway departments, agencies, ministries, other units and central units?

☐ VERY GOOD ☐ GOOD ☐ SATISFACTORY ☐ POOR ☐ VERY POOR

24. How do you rate the application and implementation of existing environmental, climate

change, adaption rules, polices guidelines?

☐ VERY GOOD ☐ GOOD ☐ SATISFACTORY ☐ POOR ☐ VERY POOR

25. Is there a need of environmental, climate change adaptation awareness programme for policy makers and other staff involved in this area?

☐ YES ☐ NO

26. If yes, what type of programme will be appropriate? (**Choose one**)

☐ Programme targeting high level policy makers (politicians)
☐ Programme targeting high level Government official
☐ Programme targeting project officers/managers
☐ Programme targeting general public

27. In your view what should be done to safeguard transport infrastructure from impact of climate change?

____

____

____

____

28. Any other things you want to mention on impact of climate change and adaptation on transport?

____

____

E. Please tell us about yourself

29. You are: ☐Male ☐ Female 30. Your country: ______________________________

31. Age: ☐ <30 years, ☐ 31-40 Years, ☐ 41-50 Years, ☐ 51-60 Yr, ☐ 61Yr.>

32. Your education: ☐Bachelor, ☐Master, ☐Doctorate

33: Your area of work____

34. Work Experience: ☐ 0-5 years, ☐ 6-10 Years, ☐11-15 years, ☐15 years above

Thank you for completing the survey!

Appendix III: Survey of Policy Maker's and Freight Forwarder's/Transport Operator's Opinion for analysis of dry port location in Lao PDR

The importance of intermodal transport is being perused in Asia. Inland dry port is one of the important nodes of intermodal transport and promotion of intermodal transport can facilitate modal shift and help reduce emissions from transport. Development of dry ports is even more important for land locked countries. There are many criteria that need to be considered for selecting/prioritizing location for dry ports.

In this background, a research on analysis of location of dry port in Lao PDR is being undertaken at the Tokyo Institute of Technology.

This survey is being conducted to evaluate location of dry ports and will be utilized to develop modal shift model in later part of the study and evaluate resulting reduction in carbon emissions – if such facilities are developed and connected by railways and inland waterways which are more environmental friendlier modes than road transport. The finding of the study will be useful to plan and develop intermodal and sustainable transport through dry ports.

Please provide **your personal view** while answering questions even some questions may refer to government programmes, policy and implementation. Your response will be treated in strict confidence. All responses will be aggregated and analyzed.

Please return the completed questionnaire **to Madan B. Regmi on or before 30 June 2011, by email mbregmi@gmail.com** or **regmi.unescap@un.org by FAX: +66-2-288-3050 or in the following address**

Madan B. Regmi	Prof. Shinya Hanaoka
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If you have any questions related to the questionnaire please contact Madan B. Regmi, by email **<mbregmi@gmail.com> or** Tel/Fax: +66-2-2881571.

Your support in timely completion of the survey questionnaire and contribution to the study will be highly appreciated.

The survey will take about 20-30 minutes. It involves pair wise comparison of two criteria/subcriteria/location (one Left and right side of column). Please use your value judgment/preference in 1-9 scale.

Part I: Evaluation of Main Criteria

Using your value judgment/preference please compare importance of the criteria on the **"left hand side"** with the criteria on the **"right hand side"** in each row and **mark with (X) or shade one box** in a row with 1-9 scale for evaluation location of dry port

Example: If you think **"Regional economic development"** is 3 times as important than **"Costs"** then you will mark **3** on Left hand Side..

	Costs	9	8	7	6	5	4	3	2	1	2	3 **X**	4	5	6	7	8	9	Regional economic development

Please indicate from in 1- 9 point scale while making **pair wise comparison** of two criteria/subcriteria in a row. Please mark only **one box** in a row.

S. No	Criteria	**Extremely important**		**Very important**		**Important**		**Slightly important**		**Equally Important**		**Slightly important**		**Important**		**Very important**		**Extremely Important**	Criteria
1	Costs	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Time
2	Costs	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Intermodal connectivity
3	Costs	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Environmental Impacts
4	Costs	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Regional economic development
5	Time	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Intermodal connectivity
6	Time	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Environmental Impacts
7	Time	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Regional economic development
8	Intermodal Connectivity	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Environmental Impacts
9	Intermodal Connectivity	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Regional economic development
10	Environmental Impacts	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Regional economic development

Part II: Evaluation of Sub-criteria

Please compare importance of the criteria/subcriteria on the **"left hand side"** with the criteria on the **"right hand side"** in each row and **mark with (X) or shade one box in a row with** 1-9 scale for evaluation location of dry port. Please mark only **one box** in a row.

Example: If you think **"Railway connectivity"** is 5 times as important than **"Inland water ways connectivity"** then you will mark 5 on Left hand Side.

	Railways	9	8	7	6	**X 5**	4	3	2	1	2	3	4	5	6	7	8	9	Inland waterways

Costs																			
11	Land acquisition costs	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Construction costs
12	Land acquisition costs	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Transport costs
13	Construction costs	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Transport costs

Intermodal transport connectivity																			
14	Highways	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Railways
15	Highways	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Inland waterways
16	Highways	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Seaports
17	Railways	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Inland waterways
18	Railways	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Seaports
19	Inland waterways	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Seaports

Environmental impacts																			
20	Construction impacts	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Operation impacts

Regional Economic Development																			
21	Proximity to market, production centres and consumers	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Government polices to develop special economic zones or free trade

																		area nearby
22	Proximity to market, production centres and consumers	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Freight Demand
23	Government polices to develop special economic zones or free trade area nearby	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Freight Demand

Part III. Preference of alternative locations with respect to criteria/sub criteria

Thanaleang, Savanakhet, Thakek and Phakse are potential location of dry ports being analyzed for transport towards Thailand. While considering criteria/subcriteria please compare preference of alternative locations in the 1-9 scale. Please mark only **one box** in a row.

Example: Considering **"land acquisition costs"** if you think "**Savanakhet"** is 4 times important/preferred than **Thanaleang** (because of cheap land price), then you will mark **4** on Right side.

Land acquisition costs																			
	Thanaleng	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Savanakhet

Land acquisition costs																			
24	Thanaleng	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Savanakhet
25	Thanaleang	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Thakek
26	Thanaleang	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Phakse
27	Savanakhet	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Thakek
28	Savanakhet	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Phakse
29	Thakek	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Phakse

Construction costs																			
30	Thanaleng	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Savanakhet
31	Thanaleang	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Thakek
32	Thanaleang	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Phakse

33	Savanakhet	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Thakek
34	Savanakhet	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Phakse
35	Thakek	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Phakse

Transportation costs

36	Thanaleng	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Savanakhet
37	Thanaleang	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Thakek
38	Thanaleang	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Phakse
39	Savanakhet	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Thakek
40	Savanakhet	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Phakse
41	Thakek	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Phakse

Total transportation time from port

42	Thanaleng	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Savannakhet
43	Thanaleang	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Thakek
44	Thanaleang	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Phakse
45	Savanakhet	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Thakek
46	Savanakhet	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Phakse
47	Thakek	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Phakse

Transport connectivity to highways

48	Thanaleng	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Savannakhet
49	Thanaleang	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Thakek
50	Thanaleang	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Phakse
51	Savanakhet	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Thakek
52	Savanakhet	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Phakse
53	Thakek	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Phakse

Transport connectivity to railways

54	Thanaleng	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Savannakhet
55	Thanaleang	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Thakek
56	Thanaleang	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Phakse

57	Savanakhet	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Thakek
58	Savanakhet	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Phakse
59	Thakek	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Phakse
Transport connectivity to inland waterways																			
60	Thanaleng	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Savannakhet
61	Thanaleang	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Thakek
62	Thanaleang	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Phakse
63	Savanakhet	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Thakek
64	Savanakhet	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Phakse
65	Thakek	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Phakse

Transport connectivity to seaports																			
66	Thanaleng	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Savannakhet
67	Thanaleang	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Thakek
68	Thanaleang	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Phakse
60	Savanakhet	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Thakek
70	Savanakhet	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Phakse
71	Thakek	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Phakse

Environmental impacts from construction																			
72	Thanaleng	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Savannakhet
73	Thanaleang	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Thakek
74	Thanaleang	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Phakse
75	Savanakhet	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Thakek
76	Savanakhet	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Phakse
77	Thakek	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Phakse

Environmental impacts from transportation operations																			
78	Thanaleng	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Savannakhet
79	Thanaleang	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Thakek
80	Thanaleang	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Phakse
81	Savanakhet	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Thakek

82	Savanakhet	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Phakse
83	Thakek	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Phakse
Proximity to market, production centres and consumers																			
84	Thanaleng	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Savannakhet
85	Thanaleang	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Thakek
86	Thanaleang	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Phakse
87	Savanakhet	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Thakek
88	Savanakhet	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Phakse
89	Thakek	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Phakse

Government polices to develop special economic zones or free trade area nearby																			
90	Thanaleng	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Savanakhet
91	Thanaleang	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Thakek
92	Thanaleang	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Phakse
93	Savanakhet	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Thakek
94	Savanakhet	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Phakse
95	Thakek	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Phakse

Freight demand																			
96	Thanaleng	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Savanakhet
97	Thanaleang	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Thakek
98	Thanaleang	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Phakse
99	Savannakhet	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Thakek
100	Savanakhet	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Phakse
101	Thakek	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Phakse

Part IV: General Information of the respondents

1. You are: ☐Male ☐ Female
2. Age: ☐ <30 years, ☐ 31-40 Years, ☐ 41-50 Years, ☐ 51-60 Yr, ☐ 61Yr.>
3. Your education: ☐Bachelor, ☐Master, ☐Doctorate
5: Your area of work___________________________6. Sector: ☐ Government ☐ Private Sector
7. Work Experience: ☐ 0-5 years, ☐ 6-10 Years, ☐11-15 years, ☐15 years above

Thank you very much for your cooperation.

Appendix IV: Questionnaire for the Stated Preference Survey (Design A)
Freight Transport between Laem Chabang Port, Thailand and Thanaleang (Vientiane), Laos/ Thanaleang (Vientiane), Laos and Laem Chabang Port, Thailand

Part I: We are seeking your feedback on freight transport mode choice decision. The options available to you are transportation using a Truck and Train. Each mode is described by the total transportation cost, total transportation time (including customs clearance, border crossing and handling at dry ports/logistics centres) and punctuality (reliability) of transport service.

The rail link between Thailand and Laos has been completed and there is a plan to construct a Logistics Centre/dry port in Thanaleang/Vientiane. It is assumed that regular freight train service will be available in near future. Assume you are considering transportation of goods in a 20 foot container from **Thailand to Laos/ Laos to Thailand.** The following 9 scenarios of freight transport by truck and train (hypothetical future scenarios) are presented to you. Please choose your preferred mode (**Truck** or **Train**) considering the given scenarios situation of transportation cost, time and punctuality of transport service.

1. **Scenario 1**

↓ Attributes\ Mode →	**Truck**	**Train**
Total Transportation Time	16 Hours	22 hours
Total Transportation cost/TEU	US$ 1800	US $ 1000
Punctuality (Delivery within hrs of schedule)	High (0-8 hrs)	High (0-8 hrs)
Which option would you choose (select one box)	☐	☐

2. **Scenario 2**

↓ Attributes\ Mode →	**Truck**	**Train**
Total Transportation Time	18 Hours	26 hours
Total Transportation cost/TEU	US$ 1800	US $ 800
Punctuality (Delivery within hrs of schedule)	Low (17-24 hrs)	High (0-8 hrs)
Which option would you choose (select one box)	☐	☐

3. **Scenario 3**

↓ Attributes\ Mode →	**Truck**	**Train**
Total Transportation Time	14 Hours	30 hours
Total Transportation cost/TEU	US$ 1600	US $ 800
Punctuality (Delivery within hrs of schedule)	High (0-8 hrs)	Low (17-24 hrs)
Which option would you choose (select one box)	☐	☐

4. **Scenario 4**

↓ Attributes\ Mode →	**Truck**	**Train**
Total Transportation Time	16 Hours	30 hours
Total Transportation cost/TEU	US$ 1800	US $ 800
Punctuality (Delivery within hrs of schedule)	Medium (9-16 hrs)	Medium (9-16 hrs)
Which option would you choose (select one box)	☐	☐

5. **Scenario 5**

↓ Attributes\ Mode →	**Truck**	**Train**
Total Transportation Time	14 Hours	26 hours
Total Transportation cost/TEU	US$ 1600	US $ 1200
Punctuality (Delivery within hrs of schedule)	Medium (9-16 hrs)	High (0-8 hrs)
Which option would you choose (select one box)	☐	☐

6. Scenario 6

Attributes\ Mode	Truck	Train
Total Transportation Time	14 Hours	26 hours
Total Transportation cost/TEU	US$ 1800	US $ 1000
Punctuality (Delivery within hrs of schedule)	Medium (9-16 hrs)	Low (17-24 hrs)
Which option would you choose (select one box)	☐	☐

7. Scenario 7

Attributes\ Mode	Truck	Train
Total Transportation Time	14 Hours	22 hours
Total Transportation cost/TEU	US$ 1800	US $ 1200
Punctuality (Delivery within hrs of schedule)	Low (17-24 hrs)	Medium (9-16 hrs)
Which option would you choose (select one box)	☐	☐

8. Scenario 8

Attributes\ Mode	Truck	Train
Total Transportation Time	18 Hours	30 hours
Total Transportation cost/TEU	US$ 1800	US $ 1200
Punctuality (Delivery within hrs of schedule)	High (0-8 hrs)	Low (17-24 hrs)
Which option would you choose (select one box)	☐	☐

9. Scenario 9

Attributes\ Mode	Truck	Train
Total Transportation Time	16 Hours	26 hours
Total Transportation cost/TEU	US$ 1600	US $ 1000
Punctuality (Delivery within hrs of schedule)	High (0-8 hrs)	Medium (9-16 hrs)
Which option would you choose (select one box)	☐	☐

Part II: General Information of the respondents and business

1. You are: ☐ Male ☐ Female
2. Age: ☐ <30 years, ☐ 31-40 Years, ☐ 41-50 Years, ☐ 51-60 Yr, ☐ 61Yr.>
3. Your education: ☐ Bachelor, ☐ Master, ☐ Doctorate
4: Years in Logistics Business: ☐ 0-5 years, ☐ 6-10 Years, ☐ 11-15 years, ☐ 15 years above
5. Indicate your order of importance (1, 2, 3) of the followings for mode choice decisions:
   a. Transportation time
   b. Transportation cost
   c. Punctuality (reliability)
6. What are other factors important for mode choice decisions?
   a. ______________________ b. ______________________
   c. ______________________ d. ________________________
7. Do you make mode choice decisions? ☐ Yes ☐ No
8. Would you use train for freight transport –if regular service is available? ☐ Yes ☐ No
9. Rate importance of dry ports/ICDs/Logistics centers for intermodal transport and in encouraging modal shift. ☐ 1 (Low) ☐ 2 ☐ 3 ☐ 4 ☐ 5 (High)

Thank you very much for your feedback.

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Stated Preference Survey (Design B)
Freight Transport between Laem Chabang Port, Thailand and Thanaleang (Vientiane), Laos/ Thanaleang (Vientiane), Laos and Laem Chabang Port, Thailand

Part I: We are seeking your feedback on freight transport mode choice decision. The options available to you are transportation using a Truck and Train. Each mode is described by the total transportation cost, total transportation time (including customs clearance, border crossing and handling at dry ports/logistics centres) and punctuality (reliability) of transport service.

The rail link between Thailand and Laos has been completed and there is a plan to construct a Logistics Centre/dry port in Thanaleang/Vientiane. It is assumed that regular freight train service will be available in near future. Assume you are considering transportation of goods in a 20 foot container from **Thailand to Laos/ Laos to Thailand.** The following 9 scenarios of freight transport by truck and train (hypothetical future scenarios) are presented to you. Please choose your preferred mode (**Truck** or **Train**) considering the given scenarios situation of transportation cost, time and punctuality of transport service.

1. **Scenario 1**

↓ Attributes\ Mode →	**Truck**	**Train**
Total Transportation Time	18 Hours	22 hours
Total Transportation cost/TEU	US$ 1400	US $ 1000
Punctuality (Delivery within hrs of schedule)	Medium (9-16 hrs)	Low (17-24 hrs)
Which option would you choose (select one box)	☐	☐

2. **Scenario 2**

↓ Attributes\ Mode →	**Truck**	**Train**
Total Transportation Time	16 Hours	26 hours
Total Transportation cost/TEU	US$ 1400	US $ 800
Punctuality (Delivery within hrs of schedule)	Low (17-24 hrs)	Low (17-24 hrs)
Which option would you choose (select one box)	☐	☐

3. **Scenario 3**

Attributes\ Mode →	**Truck**	**Train**
Total Transportation Time	18 Hours	22 hours
Total Transportation cost/TEU	US$ 1600	US $ 800
Punctuality (Delivery within hrs of schedule)	Medium (9-16 hrs)	Medium (9-16 hrs)
Which option would you choose (select one box)	☐	☐

4. **Scenario 4**

↓ Attributes\ Mode →	**Truck**	**Train**
Total Transportation Time	14 Hours	30 hours
Total Transportation cost/TEU	US$ 1400	US $ 1000
Punctuality (Delivery within hrs of schedule)	Low (17-24 hrs)	Medium (9-16 hrs)
Which option would you choose (select one box)	☐	☐

5. **Scenario 5**

↓ Attributes\ Mode →	**Truck**	**Train**
Total Transportation Time	16 Hours	30 hours
Total Transportation cost/TEU	US$ 1400	US $ 1200
Punctuality (Delivery within hrs of schedule)	Medium (9-16 hrs)	High (0-8 hrs)
Which option would you choose (select one box)	☐	☐

6. **Scenario 6**

↓ Attributes\ Mode →	**Truck**	**Train**
Total Transportation Time	18 Hours	26 hours
Total Transportation cost/TEU	US$ 1400	US $ 1200
Punctuality (Delivery within hrs of schedule)	High (0-8 hrs)	Medium (9-16 hrs)
Which option would you choose (select one box)	☐	☐

7. **Scenario 7**

↓ Attributes\ Mode →	**Truck**	**Train**
Total Transportation Time	14 Hours	22 hours
Total Transportation cost/TEU	US$ 1400	US $ 800
Punctuality (Delivery within hrs of schedule)	High (0-8 hrs)	High (0-8 hrs)
Which option would you choose (select one box)	☐	☐

8. **Scenario 8**

↓ Attributes\ Mode →	**Truck**	**Train**
Total Transportation Time	18 Hours	30 hours
Total Transportation cost/TEU	US$ 1600	US $ 1000
Punctuality (Delivery within hrs of schedule)	Low (17-24 hrs)	High (0-8 hrs)
Which option would you choose (select one box)	☐	☐

9. **Scenario 9**

↓ Attributes\ Mode →	**Truck**	**Train**
Total Transportation Time	16 Hours	22 hours
Total Transportation cost/TEU	US$ 1600	US $ 1200
Punctuality (Delivery within hrs of schedule)	Low (17-24 hrs)	Low (17-24 hrs)
Which option would you choose (select one box)	☐	☐

Part II: General Information of the respondents and business

1. You are: ☐Male ☐ Female
2. Age: ☐ <30 years, ☐ 31-40 Years, ☐ 41-50 Years, ☐ 51-60 Yr, ☐ 61Yr.>
3. Your education: ☐Bachelor, ☐Master, ☐Doctorate
4: Years in Logistics Business: ☐ 0-5 years, ☐ 6-10 Years, ☐11-15 years, ☐15 years above
5. Indicate your order of importance (1, 2, 3) of the followings for mode choice decisions:
   a. Transportation time
   b. Transportation cost
   c. Punctuality (reliability)
6. What are other factors important for mode choice decisions?
   a. ________________________ b. ________________________
   c. ________________________ d. __________________________
7. Do you make mode choice decisions? ☐ Yes ☐ No
8. Would you use train for freight transport –if regular service is available? ☐ Yes ☐ No
9. Rate importance of dry ports/ICDs/Logistics centers for intermodal transport and in encouraging modal shift. ☐ 1 (Low) ☐ 2 ☐ 3 ☐ 4 ☐ 5 (High)

Thank you very much for your feedback.

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