Final report Technical Assistant

Vietnam's Nationally Determined Contribution

Climate Change Adaptation in the Road Transport Sector and Mitigation of Greenhouse Gas Emissions in the Transport Sector

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Foreword

Vietnam's Nationally Determined Contribution (NDC) under the United Nations Framework Convention on Climate Change (UNFCCC) comprises two elements, namely mitigation and adaptation. Vietnam's NDC states that climate change adaptation must be linked to sustainable development. A clear link is also recognized between the mitigation and adaptation elements of the NDC.

The Vietnamese government has pledged to reduce the country's greenhouse gas (GHG) emissions in order to meet the Paris Agreement's goal of limiting global warming to well below 2 degrees Celsius, preferably to 1.5 degrees Celsius, compared to pre-industrial levels. In 2014, the transport sector contributed around 18 percent of energy-related GHG emissions in Vietnam. It is projected under a business-as-usual (BAU) scenario that the emissions will increase dramatically, by 2.89 times, between 2014 and 2030. Vietnam's current NDC provides a comprehensive set of mitigation actions in the transport sector, including switching to lower-carbon fuels (compressed natural gas, or CNG, in urban buses; biofuels for road vehicles) and using domestic resources.

The Vietnamese government has identified an adaptation strategy that includes enhancing adaptation efficiency by strengthening state management and resources; increasing the resilience and adaptive capacity of communities, economic sectors, and ecological systems; and reducing disaster risks and minimizing damages, getting ready to cope with increased natural disasters and climate extremes due to climate change. With regard to the road sector, Vietnam's updated 2020 NDC recognizes that both national and local road networks are at risk of being heavily impacted by climate change. For a sustainable and climate adaptive road network, an adaptation facilitation envelope that is covered by a National Climate Change Adaptation Policy to create a Financial Space by Master Planning through Climate-Aware and Adaptation Regulatory Framework should be defined.

A mitigation report prepared by the World Bank's Vietnam country and local teams, *Vietnam's Nationally Determined Contribution: Mitigation of Greenhouse Gases Emissions in the Transport Sector,* with two components—E19 (Promotion of biofuels for vehicles) and E20 (Promotion of CNG buses in transportation)—presents the efforts and achievements in deploying biofuels for road vehicles and promotion of CNG buses in urban areas in Vietnam, analyzes the barriers and possible measures for promoting the use of biofuels for road vehicle and CNG buses, and estimates the impact on GHG emissions in the BAU scenario and the mitigation scenario.

The mitigation report features a comprehensive overview of barriers for promoting the uptake of biofuels for road vehicles and CNG buses in urban areas in Vietnam and uses a bottom-up forecasting approach and analyses to quantify the impact of biofuels and CNG buses on GHG emissions from the transport sector by 2030. Based on result findings, our analysis informs policy makers and other key stakeholders about policy options to promote biofuels and CNG buses.

A climate adaptation report prepared by the World Bank's Vietnam country and technical team, *Vietnam's Nationally Determined Contribution: Climate Change Adaptation in the Transport Sector,* presents the achievement in establishing the adaptation facilitation by the Master Road Network Planning Vision 2050 which was under assessment of climate adaptation, the efforts on improvement of the climate adaption regulatory framework for road transport sector.

The adaptation report defines specific technical standards and specifications for improvement. The report also measures for climate adaptation based on a review of the existing regulatory framework for the road transport sector, international best practice in the Vietnamese context, and the experience of climate change impacts and climate resilience in Vietnam. This report will help the Ministry of Transport (MoT) develop a road map to implement the next steps.

I am grateful for the close collaboration between the World Bank and MoT, through the Department of Environment and the Department of Science Technology, Environment and International Corporation, Directorate for Roads of Vietnam.

This report has been prepared at a critical time. The government of Vietnam is setting out its vision and strategy for climate-smart transport with the goal of minimizing the carbon footprint of the transport sector while ensuring its resilience against future risks. I expect this study will provide direction for policy makers to explore suitable policy instruments that facilitate the deployment of biofuels and CNG buses in Vietnam, and to establish the climate adaptation regulatory framework under a national climate adaptation policy that contributes to Vietnam developing a low-carbon and climate-resilient transport sector.

Le Anh Tuan
Vice Minister
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Vietnam

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Technical Assistance Vietnam's Nationally Determined Contribution:

Climate Change Adaptation in the Transport Sector

World Bank Support Team

Final Report

WORLD BANK GROUP

Abbreviations and Acronyms

ADB	Asian Development Bank
CC	Climate Change
CAP	Climate Action Plan
CCA	Climate Change Adaptation
CCM	Climate Change Mitigation
CCR	Climate Change Resilience
CRM	Climate Resilience Management
CVA	Climate Vulnerability Assessment
CIF	Climate Investment Funds (CIF).
CRM	Climate Resilience Management
DoR	Department of Roads
DRM	Disaster Risk Management
DRVN	Directorate for Roads of Việt Nam
GFDRR	Global Facility for Disaster Reduction and Recovery)
LRAMP	Local Roads Asset Management Project
MONRE	Ministry of Natural Resources and Environment
MoT	Ministry of Transport
MRNP	Master Road Network Plan
NAP	National Adaptation Plan
NAPCC	National Action Plan on Climate Change
NDC	National Determined Contribution
SER	Strategic Environment Assessment Report
SLR	Sea Level Rise
TA	Technical Assistance
ToR	Terms of Reference
UNFCC	United Nations Framework Convention on Climate Change
WB	World Bank

Contents

Executive Summary

Introduction

Vietnam's Nationally Determined Contribution (NDC) under the United Nations Framework Convention on Climate Change (UNFCCC) defines that climate change adaptation must be linked to sustainable development. A clear link is also recognized between the mitigation and adaptation elements of the NDC. The identified adaptation strategic tasks are: (i) enhancing adaptation efficiency through strengthening state management and resources; (ii) increasing the resilience and adaptive capacity of communities, economic sectors and ecological systems; (iii) reducing disaster risks and minimizing damages, getting ready to cope with increased natural disasters and climate extremes due to climate change. As regards the road sector, the updated NDC recognizes that both national and local road networks are at risk of being heavily impacted by climate change.

The current Technical Assistance (TA) as a whole comprises both Mitigation and Adaptation elements. The Adaptation TA has two complementary objectives:

1. Advice on the embedment of climate resilience adaptation into transport planning and implementation at National and Local levels.

2. Reviewing and recommending improvement to the regulatory framework relevant to the design, construction and maintenance of climate resilient roads and bridges in Vietnam.

In line with the TA objectives the following work has been undertaken:

1. Inception Report: submitted in December 2020.

2. Review and comment on two MoT documents: "Vietnam Road Network Master Planning" and "Strategic Environmental Assessment Report" were submitted on 15th March 2021.

3. A review of road and bridges design standards and specifications relevant to climate impact.

4. Summary of key climate change update requirements for the regulatory framework.

5. Discussion of feasibility of revisions in standards, practices, and specifications with key decision makers in DRVN/MoT as part of Project Workshop.

This document reports on items 2-5 above, and additionally contains a number of annexes, as follows:

Annex A	A listing of Relevant Domestic, Regional and International Guidance on Climate Change Resilience	A listing of references on relevant domestic, regional and international guidance, standards and best practices in climate change adaptation.
Annex B	Summaries of Key Domestic, Regional and International Guidance and Experience with Integration of CCR in Transport Planning	A listing of references and responding key contents of knowledges and experience of Integration of CCR in Transport Planning
Annex C	Design, construction and maintenance standards review for climate adaptation.	Details of the review and recommendations to strengthen key standards relating to road and bridge design, construction and maintenance for climate adaptation.
Annex D	Technical Issues from Key Informant Interview	Technical Issues from Key Informant Interview for experiences and practical lessons to be learnt of climate change adaptation.
Annex E	Working Papers by Team Members	Detailed working papers by WB TA Team members that formed the basis for the main report text.
Annex F	NDC – Climate Adaptation Workshop Report	Notes on the NDC – Climate Adaptation Workshop and discussion outputs for final report.

MoT Document Review

Reviews and comments were requested from the Adaptation Team on the following documents:

- Document A: Strategic Environmental Assessment Report.
- Document B: Vietnam Road Network Master Planning

The TA Team comments on the draft version of the Master Planning and report as summarized in Table ES1.

TABLE ES1. **Summary of NDC – CCA Team Comments**

Adaptation Issue in Noted WB ToR	Recommended Activities
1. CRA linked to sustainable development.	Revise MP for strengthening sustainable development links to CCA
2. Key sectors and regions for CCA	Revise MP & SER with further discussion of CCA of key regions
3. CCA for urban infrastructure.	Revise MP & SER with further discussion on the CRA and urban infrastructure
4. Appreciation that design standards not flexible enough for CCA.	Revise MP & SER with addition of analysis on design standards/guideline for CR
5. Review of existing road and bridges standards and specifications.	None
6. Recommend improvement of the technical standards.	None
7, Way forward to apply recommendations,	Revise MP & SER to add mapping to CVA
8, An understanding of the relationships between CC cause and effect within an holistic matrix.	Revise MP with more detailed information
9. Climate resilience to be planned and implemented within a CRM framework.	Revise MP to show the planning & plan implementation follows CRM framework Revise SER with the CRM assessment
10. Strengthening drainage infrastructure as a priority.	Revise MP include drainage infrastructure strengthening
11. Develop good practice guidance on appropriate, technical design and construction standards.	None
12. Review of relevant regional and international guidance and best practices for CCA	None
13. Identification of opportunities to mainstream CCA in Vietnam road, bridge and drainage systems design and construction.	Revise MP to identify opportunities of mainstream CCA in Vietnam road, bridge and drainage systems design and construction.
14. The requirements for CVA at different project levels and CCA at different road classification levels.	Revise MP & SER briefing the requirements for CVA at different project levels and CRA at different road classification levels
15. Risk prioritization; the provision of guidance and requirements on the selection and cost assessment of CCA.	Revise MP & SER briefing for the Risk prioritization & requirements on the selection and cost assessment of CCA.

The recommendations on MP and SER, and the contributions to SER from NDC – CCA team have been included in the final version of the MP and SER. The Master Planning of Road Network Development 2021-2030, vision 2050 has been approved by Prime Minister of Vietnam, the Decision No.1454/QĐ-Ttg dated 1/9/2021.

Climate Change in Vietnam

Global climate change projections indicate a combination of gradual changes to average climatic conditions and increasing frequency, severity and location of extreme weather or "shock" events. The current climatic environment, with its variability and frequency of extreme weather events, when associated with its physical environment, makes Vietnam potentially highly susceptible to climate impacts. The risks arising from these impacts on the road network are considerably increased when the likelihood of increasing climate threats from future climate change is taken into account.

Specific impacts have been identified as a consequence of

- Increased rainfall
- Storms
- Increased temperature
- Sea level rise

The consequent impacts are then grouped in terms of

- Road Pavement
- Road Cuts and Embankment
- Subgrade
- Bridge and Drainage
- Project Preparation & Design
- Road Works Construction
- Road Network Management & Maintenance

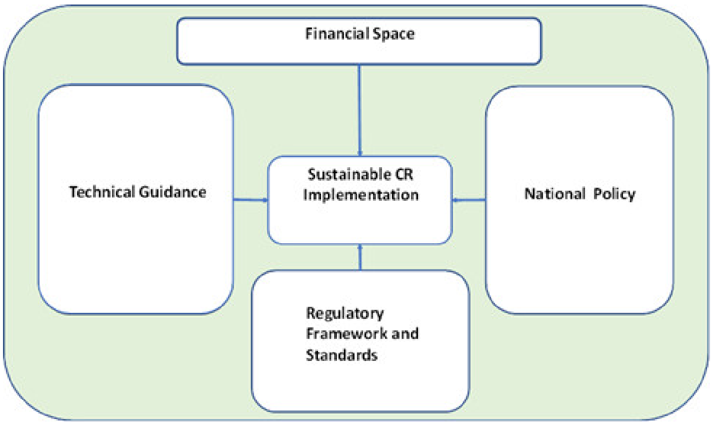
Regional variations occur in adaptation requirements in response to regional variations in climate threats:

Red River Delta and Mid-N region	Flood, storm, cyclone
Northern Coastal area	Storm surge flood, storm, flood, cyclone
Northern Mountains	Flash flood, flood, landslide, cyclone
Central Coastal region	Storm surge flood, flash flood, cyclone, salt-water intrusion.
Highland area	Drought, flash flood, forest fire
South East region	Storm, flash flood, forest fire
Coastal area of the Mekong Delta	Flood salt-water intrusion, forest fire
Central Mekong Delta	Flood, drought, whirlwind, storm

A Framework for Climate Change Adaptation

Figure ES1 indicates the key elements of a framework within which embedment of sustainable climate resilience has to take place.

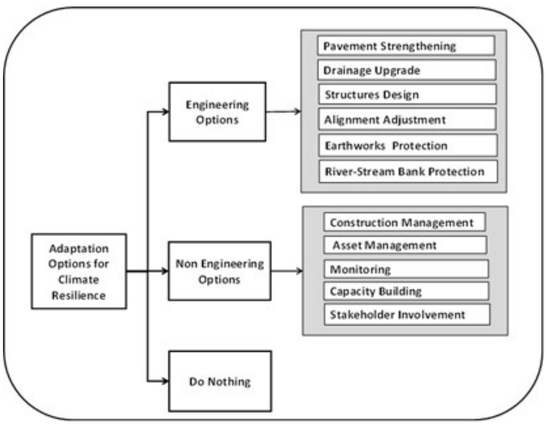
FIGURE ES1. **Strategic Framework for Sustainable Climate Resilience**



National Policy, in conjunction with Ministerial policies and directives, is the basic driver for the adoption of climate resilience and adaptation as a required process in road projects. **Technical Guidance** on the appropriate selection, design and construction of adaptation measures is an essential tool. Guidelines should also serve to interpret standards for application in an appropriate and logical manner. **Regulatory Framework and Standards** provide the necessary environment within which climate resilience can be effectively applied. **Financial Space**. Whilst the provision of effective well-designed climate resilience is certainly beneficial in terms of whole-life engineering and economic terms, it does entail increased initial design and construction costs. The availability of financial space will govern early decisions on climate resilience and the prioritization of projects or specific assets. The identification and allocation of finance at an early stage therefore becomes a key component in the sustainable adaptation matrix.

Relevant adaptation project level interventions can be broadly summarized in Figure ES2

FIGURE ES2. **Project Adaptation Options**



The Vietnam Regulatory Framework for Climate Change Adaptation

Key road design standards are:

i) TCVN 4054:2005 - Highway – Specifications for design

ii) TCVN 5729:2012 - Expressway – Specifications for design

iii) TCXD 104:2007 – Urban road – Specification for design

iv) TCVN 10380:2014 - Rural Roads – Specifications for Design

v) TCVN 9845:2013 – Calculation of flood flow characteristics

vi) 22 TCN – 211 – 06 – Flexible Pavement Design Specification

vii) 22TCN – 263 – 2000 – Road Survey Specification

The design standards of Vietnam provide regulations for design work, with regulations that are either general, or sometimes have specific provisions for some cases. Design standards are therefore in the form of a semi-standard (with regulations on design principles), a semi-guideline (with specific provisions for cases). The general transport infrastructure design standards in Vietnam are not reviewed and updated to keep up with changes in policy, institutions and natural conditions.

In summary, amendments to road-related standards need, in general, to address the following:

1. Selection road alignment and elevation during road work planning and preliminary design under climate change scenario considering inter-impact between road infrastructure and climate using appropriate hydraulic analysis tool;

2. Selection of pavement structure pavement thickness, stable at high temperature and salt-resistant materials during upgrading, improvement and re/new construction;

3. Underground water drainage options include pavement drainage options;

4. Survey the hydrological regime, calculate and analysis hydraulic conditions of drainage structures with consideration of the additional rainfall and sea level rising under the climate change scenario;

5. Ensure road geometric design for vertical elevation, super-elevation, sight distance,… in critical weather conditions follows climate change;

6. Design bioengineering options to block wind and sand; and planting and restoring mangrove forests to break waves;

7. Design of bioengineering options on slope to minimize the impact of temperature, increased rain and flood;

8. Strengthen flood and storm prevention to minimize the negative impacts of weather on national highways.

Table 5.1. in Annex C is the main text provides a detailed review of road standards

As a general comment it should be noted that standards involving climate data and related hydrological data should require the use of assessed future data rather than being totally dependent on historic data. This time frame of this future climate data should be compatible with the design life of the road asset being considered, depended on the road grade, for example around 15 years for a road pavement surface or 100 years or more for a large bridge.

Good Practice for Climate Change Adaptation for Road Networks

Following-on from the review of the review of the MP and SER documents, good practices for Climate Action Plans (CAP) (Bach Tan Sinh et al, 2015) in road network planning are summarized as follows:

Coordination by local staff with external technical inputs.	The CAP process is coordinated by local government staff with technical support from external experts as required.
Departments involved in implementation.	Key technical departments involved in implementing plans are also part of the planning team.
Interaction/collaboration between technical specialists, departments, services.	Formal collaboration and consultation mechanisms exist to ensure that different technical departments, specialists and government service units can review and comment on the draft plan.
Consultation with vulnerable community groups.	Social groups who are most vulnerable to climate impacts are specifically involved in consultations to assess vulnerability, risk and alternative adaptation measures.
Responsibility for implementation assigned.	Clear responsibility for implementation of CAP recommendations is assigned to specific agencies
Iterative process (shared learning)	The CAP process is iterative: some parts of the process have been repeated as information improves, lessons are widely shared and documented and feedback is provided to contributors.
Local commitment.	Local political commitment to the CAP process is high, as demonstrated by executive-level support.
Driven by local interest.	CAP procedures and priorities are driven by local context and respond to locally determined priorities.
Experience driven by international donor.	The planning process responds to advice from international donors and their technical experts and to priorities they have identified.
Request for additional information.	Local planners request additional information from external expert consultants, national government or other local departments to respond to emerging issues as the plan develops.
Prioritization of adaptation measures.	The CAP establishes a limited number of priority measures for implementation.
Recommendations focus on key vulnerabilities	The priority recommendations respond clearly to vulnerabilities identified in the plan.
Implementation of recommendations.	Priority recommendations in the original CAP are implemented by local government
Recommendations supported by implementing agency.	The CAP recommendations are reviewed and approved by the technical departments responsible for their implementation.

Financing of implementation measures	Financial resources for implementation are identified in the CAP
Barriers/incentives to implementation	The CAP explicitly identifies any notable barriers or incentives that could prevent or support implementation of recommendations
Monitoring	The CAP includes mechanisms for monitoring implementation and updating the plan
Use of best available science	Climate change adaptation planning uses the most recent available climate projections, including estimates of uncertainty
Availability of climate information	Climate information has been made available to the public as part of the planning and consultation process
Assessment of climate impacts	Climate projections have been used to assess likely impacts from climate change
Application of hydrological models	Hydrological modelling has been applied to assess risks of flooding from rivers or sea-level rise
Vulnerability assessment	A formal vulnerability assessment has been undertaken to demonstrate which groups and sites are most vulnerable to climate impacts
Risk assessment	A formal risk assessment has been undertaken, either quantitative or qualitative, explicitly assessing the probability and magnitude of damage from climate impacts
Risk assessment used in prioritization	Conclusions from risk assessment have been explicitly used in determining priorities for adaptation recommendations

International experience indicates that the development of new adaptation measures as a whole can be summarized under the following headings:

A. Organizational and Decision-Making Processes

B. Technical Options

C. Procedural and Operational Options

D. Information Flow and ICT Support

E. Decision and Risk Models

F. Legislative Options

Measures under these headings are assembled and prioritized into a way forward roadmap (Iraklis Stamos, Evangelos Mitsakis, Josep Maria Salanova Grau, Sep 2015).

Based on the international good practice of Adaptation Measures roadmap and Vietnam climate change adaptation context, TA group propose 53 measures/sub-measures of climate change adaptation, the way forward road map and prioritization.

Summary of Experience on Updating Standards

Incentives to include climate adaptation in programmes or individual projects are shaped by the policy and the regulatory environment (Standards, Decrees, Guides, Specification). Governments or individual Ministries can facilitate climate-resilient infrastructure by removing policy or regulatory constraints, or by adding regulatory requirements to consider climate risks and facilitate adaptation uptake. An interim list of general priority areas to be addressed is presented in Table ES2

TABLE ES2. **Regulatory Amendment**

General Priority Areas	Amendments/Additions
Climate Resilience Policy	Road network to be planned, design, constructed and maintained to defined climate resilient levels.
Climate Resilience Planning and Costing	Climate resilience to be a mandatory consideration in all national, provincial, local plans.
Project Life Cycle	Climate resilience should be a mandatory consideration on all stages of the project or road life cycle: Planning, Feasibility, Design, Construction and Maintenance.
Climate Change Data	For relevant standards, forecasted future climate and hydrological data to be used rather than historical data. Time span of data to be in line with design life of individual assets.
Climate Resilience Adaptation Measures	Individual road asset design standards and associated cost norms to be amended to take account of climate change issues, for example: • Pavement (supported drainage pavement structure /anti-erosion/ wheel rutting resistance/…) • Drainage system (efficiently comprehensive system, appropriate flow discharge, natural condition based position/span) • Alignment geometry (natural based horizontal alignment; appropriate levels follows drainage system and foods level) • Bridge deck spans and levels • Earthwork slopes/benches/drainages • Bioengineering • Materials (strength/resistance to soaking) • Safety (landslide/flood warnings) • Culverts sizes and levels • etc
Maintenance Planning and Implementation (	Climate vulnerability and consequent resilience adaptation to included in all maintenance planning models together with any require adjustment to maintenance method and norms.
Climate Resilience Monitoring and Evaluation	Inclusion of climate resilience monitoring and evaluation for all major projects (National and Provincial?); includes effectiveness of adaptation measures and actual climate records.

Ways Forward

DFID-funded 2019 Climate Change Management Guidelines identified a series of steps required for updating standards and design guides to take account of climate adaptations:

1. Review all existing standards, guides, manuals and similar publications/documents to determine whether climate threats and associated adaptation are adequately covered.

2. Determine which documents are being updated (or are soon to be updated) and initiate actions to incorporate adaptation in their Terms of Reference.

3. For those with no immediate plans to update, decide whether to bring forward the update or whether to produce some form of augmentation.

4. Form a multidisciplinary/multisector working group (or groups) to scope out and deliver the necessary adaptation augmentation requirements based on the prioritization set out above.

An essential key 1st step is recommended as an Adaptation Workshop with the following key objectives:

1. Policy-planning issues

2. Regulatory framework issues

3. Engineering adaptation

4. Non-engineering adaptation

5. Challenges to embedment

6. Way forward details

1. Introduction

1.1 Background

Vietnam's Nationally Determined Contribution (NDC) under the United Nations Framework Convention on Climate Change (UNFCCC) defines that climate change adaptation must be linked to sustainable development. It sets a number of priority actions that include producing socio-economic development plans based on climate change scenarios. It focuses on key sectors and regions; improving regulations and technical standards for infrastructure; construction of climate change resilient urban infrastructure; and strengthening drainage infrastructure. A clear link is recognized between the mitigation and adaptation elements of the NDC.

The identified adaptation strategic tasks are: (i) enhancing adaptation efficiency through strengthening state management and resources; (ii) increasing the resilience and adaptive capacity of communities, economic sectors and ecological systems; (iii) reducing disaster risks and minimizing damages, getting ready to cope with increased natural disasters and climate extremes due to climate change. These strategic tasks are consolidated in the National Adaptation Plan (NAP), and the National Action Plan on Climate Change (NAPCC).

As regards the road sector the updated NDC recognizes that both national and local road networks are at risk of being heavily impacted by climate change.

1.2 TA Objectives

The TA as whole comprises both Mitigation and Adaptation elements and at a strategic level will leverage and complement the World Bank's sectoral engagements, which include a move towards Low Carbon and Resilient Transport.

The Adaptation TA has two complementary objectives:

1. Advice on the embedment of climate resilience adaptation into transport planning and implementation at National and Local levels.
2. Reviewing and recommending improvement to the regulatory framework relevant to the design, construction and maintenance of climate resilient roads and bridges in Vietnam.

These objectives are derived from key strategic tasks identified in the 2020 NDC for climate change, which include:

"Improving the legal framework to promote adaptation actions; implementing the NAP, applying the monitoring and evaluation system for climate change adaptation activities at the national and provincial levels; integrating climate change adaptation into policies, strategies, plans, programmes and projects."

1.3 Work Undertaken

In line with the TA objectives the following work has been undertaken:

1. Inception Report: An inception report with work plan was completed in October 2020 and a final version re-submitted in December 2020.

2. Review and comment on two MoT documents: Support PMU3 local consultant to review and improve the revised "Vietnam Road Network Master Planning" and "Strategic Environmental Assessment Report" as part of the advice on the embedment of climate resilience adaptation into transport planning. Comments and contributions were submitted on 15th March 2021.

3. Document Review: Review of road and bridges design standards and specifications relevant to climate impact. Review of relevant domestic, regional and international guidance and best practices and experience with integration of Climate Change Resilience (CCR) in transport planning. Output from this review is included as part of this report.

4. Mainstreaming Opportunities: Summarize key update requirements for the regulatory framework. Identification of opportunities to revise documentation, and mainstream climate considerations into transport planning and onward into the project life cycle. Output is included as part of this report.

5. Implementation Options: Discussion of feasibility of revisions in standards, practices, and specifications with key decision makers in DRVN/MoT. Recognize potential obstacles, knowledge gaps and constraints to climate resilience embedment in planning identify pathways forward to overcome these.

6. Workshop and Final Reporting.

This document reports on items 2-5 above, and additionally includes a number of annexes containing support detail.

1.4 Report Structure

The contents of this document following this Introduction are summarised in Table 1.1

TABLE 1.1 **Report Structure**

Section	Title	Description
Chapter 2	MoT Document Review	Summary of comments made by the WB Team on two documents.
Chapter 3	Climate Change in Vietnam	A summary of climate change in Vietnam and its regional variation together with the likely impacts on road infrastructure.
Chapter 4	A Framework for Climate Change Adaptation	A framework is presented of the key elements that facilitate the mainstreaming climate resilience adaptation. Key adaptation options are listed.
Chapter 5	The Vietnam Regulatory Framework for Climate Change Adaptation	A concise review of the current Vietnam regulatory system as it relates to road and bridge planning, design, construction and maintenance.
Chapter 6	Good Practice in Climate Change Adaptation for Road Networks	A summary of good practice in mainstreaming climate change adaptation based on international experience.
Chapter 7	Adaptation Measures in the Vietnam Context	A review of the measure discussed in Chapter 6 as they could be applied in the Vietnam climate change environments.
Chapter 8	Summary of Experience on Updating Standards	A compilation of lessons to be learnt from updating of regulatory frameworks for climate change.
Chapter 9	Ways Forward	A summary of the next key steps to be taken to in moving forward the mainstreaming of climate change adaptation options and the updating of the related standards and guidance in planning, design, construction and maintenance of Vietnam road networks.
Annex A	A listing of Relevant Domestic, Regional and International Guidance on Climate Change Resilience	The list of relevant national, regional and international references includes climate change adaptation guidelines, standards and methods.
Annex B	Summaries of Key Domestic, Regional and International Guidance and Experience with Integration of CCR in Transport Planning	List of references together with a summary of knowledge and experience on integrating climate change adaptation into transport planning..
Annex C	Design, construction and maintenance standards review for climate adaptation	Details of the review and recommendations to strengthen key standards relating to road and bridge design, construction and maintenance for climate adaptation
Annex D	Technical Issues from Key Informant Interview	Short bibliographic summaries of key references taken from the Annex A list that are applicable to the TA aims.
Annex E	Working Papers by Team Members	Detailed working papers by WB TA Team members that formed the basis for the main report text.

2. MoT Document Review

Reviews and comments were requested from the TA Adaptation Team on the following documents:

- Document A: Strategic Environmental Assessment Report for the Vietnam Road Network Master Planning.
- Document B: Vietnam Road Network Master Planning in 2021-2030 period, Vision 2050.

The TA Team comments and recommendations are summarized in Table 2.1

Besides the comments below, the TA Team provided a direct assessment on the Strategic Environmental Assessment Report in order for the MoT to finalize the report. It was reported by DRVN in a project progress meeting on the 8th July 2021 that all of recommendations and contributions from the TA Team have been incorporated in the Strategic Environmental Assessment Report submitted to Vietnam Government. High appreciation was confirmed from the Ministry of Science, Technology and Environment for the Report.

The Vietnam Road Network Master Planning in 2021-2030 period, vision 2050 was approved by Prime Minister dated 1st Sep 2021.

Comments and recommendations from TA Team for contributing to the first versions of the MoT documents are summarized in Table 2.1.

TABLE 2.1. **Summary of Team Comments on the draft version of the reviewed documents**

Adaptation Issue in WB ToR	Documents reviewed & Recommendations		
	Document No. B	Document No. A	Recommended Activities
1. Climate Change Adaptation (CCA) linked to sustainable development.	No strong links made.	General link made on climate risk to transport development and inclusion in planning within environment context.	Revise MP for strengthening sustainable development links to CCA..
2. Key sectors and regions for CCA	Some limited discussion on key regions.	CC summarised by region.	Revise MP & SER with further discussion of CRA of key regions
3. CCA for urban infrastructure.	No specific mention of urban situation.	Urban network mentioned but not in context of CCA.	Revise MP & SER with further discussion on the CCA and urban infrastructure.
4. Appreciation that design standards not flexible enough for CCA.	Not mentioned.	Not mentioned.	Revise MP & SER with addition of analysis on design standards/guideline for CR.

Adaptation Issue in WB ToR	Documents reviewed & Recommendations		
	Document No. B	Document No. A	Recommended Activities
5. Review of existing road and bridges standards and specifications.	Listing of relevant standards etc	Summary of legal basis for planning. Listing of legal basis documents.	None.
6. Recommend improvement of the technical standards.	No mention.	Updating of hydrological designs recommended as well legal/policy framework from environment aspect. No CCA.	None.
7, Way forward to apply recommendations.	No mention.	CC within environmental model into MP.	Revise MP & SER to add mapping to CR.
8, An understanding of the relationships between CC cause and effect within an holistic matrix.	General overview on climate impacts.	CCA summarised in general. Environmental impact context.	Revise MP with more detailed information.
9. Climate resilience to be planned and implemented within a CRM framework.	No mention.	Not mentioned.	Revise MP to show the planning & plan implementation follows CRM framework Revise SER with the CRM assessment.
10. Strengthening drainage infrastructure as a priority.	No specific mention.	Noted in reference to flooding as an environmental issue.	Revise MP include drainage infrastructure strengthening.
11. Develop good practice guidance on appropriate technical design and construction standards.	Not mentioned.	Guidance and guidelines on SER in planning only; no specific CR inclusion.	None
12. Review of relevant regional and international guidance and best practices for CCA.	International, regional experience not mentioned.	Not covered	None
13. Identification of opportunities to mainstream CCA in Vietnam road, bridge and drainage systems design and construction.	Not mentioned.	Hydraulic issues to be covered in MP in context of environmental impact.	Revise MP to identify opportunities of mainstream CCA in Vietnam road, bridge and drainage systems design and construction.
14. The requirements for Climate Vulnerability Analysis (CVA) at different project levels and CCA at different road classification levels.	Not mentioned.	Not Mentioned.	Revise MP & SER briefing the requirements for CVA at different project levels and CCA at different road classification levels.
15. Risk prioritization; the provision of guidance and requirements on the selection and cost assessment of CCA.	Not mentioned.	Not mentioned.	Revise MP & SER briefing for the Risk prioritization & requirements on the selection and cost assessment of CRA.

3. Climate Change in Vietnam

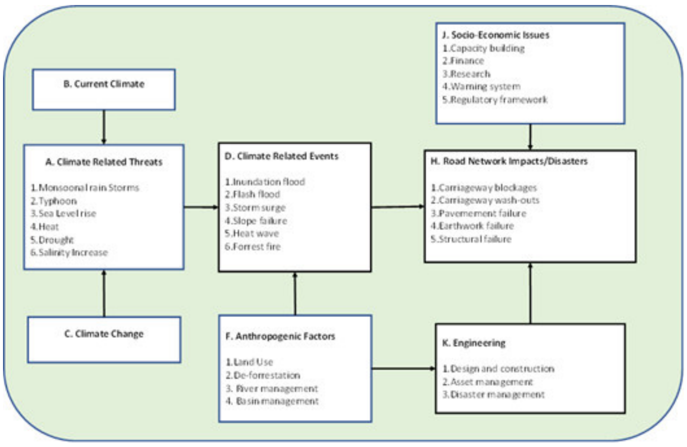
3.1 Climate Change and Consequences

There is now general agreement on the broad issue that climate change is occurring and will continue to occur over the coming decades and that it will involve issues such as a rise in sea level, changes in seasonal rainfall; increased temperature and increased major climatic events. Reports from the Intergovernmental Panel on Climate Change (IPCC) clearly show that land surface air temperatures and sea surface temperatures have both increased in the course of the last century with maximum and minimum temperatures increasing over land since the mid–20th century (IPCC ,2014, Ref 1047).

Global climate change projections indicate a combination of gradual changes to average climatic conditions and increasing frequency, severity and location of extreme weather or "shock" events. Gradual changes related to climatic variables are those which are experienced over a period of time from months to years, decades or even centuries. Extreme events are typically those which occur suddenly, sometimes with limited warning, typically over a period of hours, days or weeks (World Bank 2017 Ref 1017). These events include heavy and/or prolonged precipitation events, heatwaves, single very hot or cold days, and prolonged periods of drought.

Figure 3.1 summarizes the framework of causes and effects that constitutes a framework within which climate change impacts and resilience adaptations may be considered.

FIGURE 3.1 **The Climate Change Impact Framework**



3.2 Climate Change Impacts on the Vietnam Road Network

The current climatic environment, with its variability and frequency of extreme weather events, when associated with its physical environment, makes Vietnam potentially highly susceptible to climate impacts. The risks arising from these impacts on the road network are considerably increased when the likelihood of increasing climate threats from future climate change is taken into account. Tables 3.1 to 3.4 summarize climate change impacts on road network assets and how they fit within the road-project cycle.

TABLE 3.1. **Hazards Related to the Increased Precipitation**

Component	Potential technical issues due to increased precipitation
Road Asset	
Road Pavement	Flooding, Flash flood results in surface degradation, rutting and erosion. Softening/weakening of pavement materials on saturation. Soil shoulder erosion. Loss of pavement layer strength results to structural damages.
Road Cuts and Embankment	Cut-slope instability (landslides, slope failure). Saturation and weakening of embankment soils result to landslides. Erosion of soil surfaces and drains. Embankment surface erosion. Excessive vegetation growth.
Subgrade	Expansion of moisture-sensitive materials. Subgrade settlement. Subgrade softening. Deformation of rigid structures. Increased sinkholes in karst areas.
Bridge and Drainage	Drainage system capacity is exceeded resulting in over-topping, erosion and/or washing out. Siltation and blocking of drains. Scour of bridge foundations, abutment erosion leading to bridge collapse. Overtopping of bridges results to damage or destruction. Damage to bridge structures by debris in floodwaters. Erosion of embankments and abutments of culverts and bridges.
Road Cycle	
Road Project Preparation and Road Design	Uncertainty of the input data results to "under-design". Increasing project cost estimation if not taken in to account at planning stage.
Road Works Construction	Excessive moisture in materials, cannot haul/place materials– construction delays. Risk of delays due to critical and long-term rain. Water damage to partially completed works. Increase construction cost due to need for more coffer dams or flood-control measures during drainage and bridge construction.
Road Network Management & Maintenance	Increased maintenance costs for pavement, shoulder, drainage. Increase maintenance works of pavement cleaning and drainage structure clearing. Critically increase emergency maintenance works in storm reason. Close major roads due to flooding and increase economic impact and road management cost.

TABLE 3.2. **Hazards Related to Increased Major Storms**

Components	Potential problems and damages due to storm
Road Assets	
Road Pavement	Flooding, Flash flood (on pavement) surface damage and erosion
Road Cuts and Embankment	Slope instability upslope and/or downslope of carriageway Road section washing out
Subgrade	Subgrade settlement and washing out
Bridges and Drainage	Siltation and blocking of drains Erosion of embankments and abutments of culverts and bridges Bridge or bridge superstructure/substructures washing out Clearance for water transport reduced – boat passage blocked
Road Cycle	
Road Project Preparation and Road Design	Poor input data for relating to critical storms/disaster results in "under-design" Increase project cost estimation against planning estimations
Road Works Construction	Increase construction cost for repairing damage due to the critical storms/ disaster during construction period Delays due to: Interrupted construction progress, time for variation order and/or damage repair compensation and/or insurance procedure.
Road Network Management & Maintenance	Critical increase of emergency maintenance works in storm reason Road closed and traffic interrupted, economic and social impacts

TABLE 3.3. **Hazards Related to Increased Temperature**

Components	Potential problems and damages due to increased temperature
Road Assets	
Road Pavement	Softening of bitumen in asphalt and accelerating permanent deformation. More rapid ageing of bituminous binders to shorten pavement life Expansion and buckling of concrete roads.
Road Cuts and Embankment	More rapid drying out and cracking Loss of vegetation (or changes of species) on side slopes due to insufficient water Increased erosion due to loss of vegetation
Bridges and Drainage	Greater expansion/contraction of bridge elements. Larger temperature gradients in thick concrete elements/structures.
Road Cycle	
Road Project Preparation and Road Design	Design method does not cover fully operating condition result to issue of "under-design." Increase project cost estimation due to required modifications
Road Works Construction	Poor work quality due to construction in critical weather, especially for HMA pavement due to longer cooling time, concrete pavement and structures due to quicker hydrated reaction, quicker drying progress of concrete and more difficult curing regime. Delays due to shortened possible construction time, and lower working productivity
Road Network Management & Maintenance	Require more maintenance works and costs for impacted structural items: bitumen pavement and concrete structures; vegetation & bio-engineering.

TABLE 3.4. **Hazards Related to Sea-Level Rise (SLR)**

Components	Potential problems and damages due to increased SLR
Road Asset	
Road Pavement	Ravelling of bitumen surface by salts and water. Increased subgrade moisture contents and reduced support.
Road Embankment	Embankment slope erosion or sliding.; Fluctuating underwater levels and increased subgrade moisture contents. Reduced and unstable subgrade soil strength.
Bridges and Drainage	Reduce discharge capacity of the drainage structures of culverts and drains, and results to flood at the inlet areas. Reduce clearance results to risks of damages due to collision between waterway transport facilities and bridge structures. Erosion and/or scour of structure foundations. Salt weathering brings risks of concrete degradation and carbonation, chloride induces corrosion to reinforcement and steel structures which all shorten structure life.
Road Cycle	
Road Project Preparation and Road Design	Increase length of bridge and size of culverts and drains. Hydraulic calculation and analysis is modified or "under-design" issue. Increase project cost.
Road Works Construction	Required modified construction method statement and modified materials. Delays at construction due to floods. Construction quality is potentially impacted.
Road Network Management & Maintenance	Increased maintenance works and costs due to deterioration of concrete and reinforcing concrete structures.

3.3 Regional Variations in Adaption Requirements

Chinowsky et al (2015 Ref 1199) extend earlier work by evaluating the implications of climate change for road infrastructure within Vietnam across a fuller range of climate change projections. They find Across 56 climate scenarios, the mean additional cost of maintaining the Vietnam road network through 2050 could amount to US$10.5 billion varying across different regions. The potential scale of these impacts reinforces climate change adaptation as an important component of planning and policy in the current and near future.

They define stressors as SLR, precipitation, temperature and flooding, while the infrastructure impacted elements are paved, gravel and earth roads. They consider some key cost issues:

- Total cost: The overall estimated costs of climate change impacts on road infrastructure (at 2010 prices and without discounting).
- Opportunity cost: The amount of paved road that could have been built with the funding that is diverted to climate change costs.
- Adaptive advantage: The benefit of adapting to climate change

Central highlands: All damage costs are from climate and flooding stressors. According to Chinowsky et al, Adaptation policy saves nearly US$100 million in the "maximum hot" scenario, which is the cost difference from expanding existing infrastructure by nearly 50 percent as opposed to a 10 percent opportunity cost for adaptation.

Mekong River delta: This region incurs the largest total and opportunity costs of all regions under the combined climate change scenarios. This can largely be attributed to SLR, given that most of this southernmost region in Vietnam is at an elevation of less than three meters. In the region's thirteen provinces, coastal inundation impacts between 14 and 99,5 percent of provincial road infrastructure.

TDSI & IMHEN, (2020) provided an assessment of climate change impacts on transport infrastructure system using an impact factor matrix and found that the road infrastructure in this area is highly vulnerable in most factors: such as temperature, rainfall, extreme natural disasters, subsidence, flooding The exceptions were drought and saline intrusion at low impact. The critical climate change was SLR combined with tidal flow was the most serious in this region due to low-lying land and soft soil.

Northern central and central coast area: Climate change impacts analysis show that impacts in this region are quite modest relative to other regions in Vietnam. However, According to Chinowsky et al, 2015 total costs reach as much as US$115.9 million under the maximum hot scenario, with an opportunity cost of 57 percent. Adaptation policy reduces this opportunity cost to 16 percent, which is a savings of US$83.7 million. Even though the median hot scenario has a lower projected impact (25 and 34 percent with and without adaptation, respectively), there is still a significant benefit to adaptation of road infrastructure. The largest damages occur in Da Nang and Phu Yen provinces.

Short and steep rivers due to terrain conditions in the northern central make impact factors of climate change are more critical. Landslide (road slope and along coastal bank), flood and extreme natural disaster also are also very high impact factors while increasing temperature, rainfall and SLR are moderate impact factors. Adaptation requirements for this region are concentrated in drainage system to improve flow discharge capacity.

Northern midlands and mountain areas: With adaptation policy this region incurs the lowest total and opportunity costs from climate change, because of the region's location away from the coast. The climate impacts from temperature, precipitation and flooding could cost as much as US$100 million, but with adaptation this is reduced to US$11 million. Adaptation policy is therefore highly effective in this region.

Red River delta: SLR impacts six percent of this region's roads, with losses as high as 21 percent in some provinces. Adaptation policy reduces total climate damage costs by nearly US$150 million under the maximum hot scenario. The opportunity cost savings from adaptation are similar across the two GCM scenarios in this region, but vary significantly without adaptation policies. This highlights the effectiveness of adaptation in reducing both the magnitude and variation of potential climate change damages. Avoiding a "worst case" scenario through adaptation policies that limit road infrastructure damages will be crucial in this region's densely populated urban areas, especially within the capital city, Hanoi.

South East: This small region contains key urban centers, including Ho Chi Minh City. Road impact losses from SLR vary across provinces from 0 percent–21 percent, with Ho Chi Minh at the upper end of this distribution. With approximately 6800 kilometers of roads, this region incurs a total cost of US$165 million in the maximum hot scenario, and a potential road loss of 1360 kilometers. Adaptation generates savings of US$122 million, which again underscores the need for pro-active infrastructure adaptation policy.

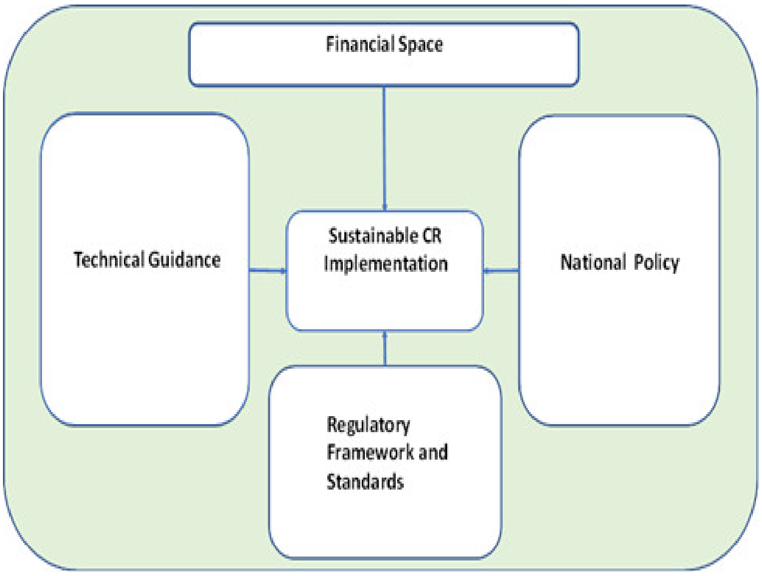
4. A Framework for Climate Change Adaptation

4.1 Key Elements

The general principles of climate impact evaluation and mitigation through engineering and non-engineering options are now understood in general terms and have been developed in a number of international documents. Work already undertaken and applied internationally has identified and defined key adaptation actions and procedures (See Annex B, Table B3). Research has also been undertaken regionally and in Vietnam which has indicated some ways forward within the Vietnam environment (See Annex B Tables B1 and B2).

What significantly remains to be achieved is the embedment of the practical best-practice solutions to overcoming climate impact challenges within the regulatory, design, construction and maintenance environments associated with the Vietnam Road Network. Figure 4.1 indicates the key elements of a framework within which this embedment of sustainable climate resilience has to take place.

FIGURE 4.1 **Strategic Framework for Sustainable Climate Resilience**



National Policy, in conjunction with Ministerial policies and directives, is the basic driver for the adoption of climate resilience and adaptation as a required process in road projects. A clear policy that lays out climate resilience targets is the basis on which the adoption of appropriate engineering and non- engineering measures are considered.

Technical Guidance on the appropriate selection, design and construction of adaptation measures is an essential tool. Whilst many of the adaptation measures are well understood by Vietnamese road practitioners, the criteria for selection and prioritization together with use of data in design requires specific guidance. Some adaptation options, such as aspects of bioengineering and innovative slope support measures may not be so well understood and require detailed guidance. Guidelines should also serve to interpret standards for application in an appropriate and logical manner.

Regulatory Framework and Standards provide the necessary environment within which climate resilience can be effectively applied. Road design engineers and contractors cannot be expected to work outside established legal regulations and standards unless given specific license to do so. The adoption of many climate resilience options requires a significant measure of flexibility and innovation that is not covered by the current regulatory framework – as discussed in the following chapters.

Financial Space. Whilst the provision of effective well-designed climate resilience is certainly beneficial in terms of whole-life engineering and economic terms, it does entail increased initial design and construction costs. The availability of financial space will govern early decisions on climate resilience and the prioritization of projects or specific assets. The identification and allocation of finance at an early project stage therefore becomes a key component in the sustainable adaptation matrix.

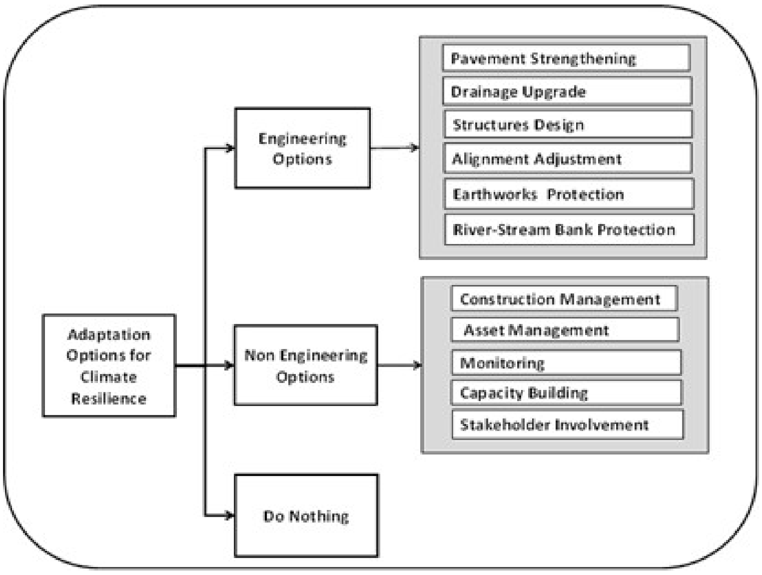
4.2 Adaptation Options

Recent Climate Engineering Adaptation Guidelines (ReCAP, 2019, Refs 1112 & 1177) provide a general adaptation strategy which includes:

- Decrease the vulnerability of transport infrastructure to changing climate conditions;
- Increase the resilience of infrastructure;
- Support planning for placement of new infrastructure in areas which are projected to have a lower risk of potentially harmful environmental changes;
- Support the identification of new and innovative construction materials and construction methods, flexible design standards, and different approaches to design to ensure infrastructure can withstand the projected changes in climate;
- Prepare Roads Authorities for rapid response/reaction to climate-related events.

In the Vietnam-specific context, the relevant project-level adaptation interventions can be broadly summarized in Figure 4.2 and described in the following paragraphs.

FIGURE 4.2. **Project-Level Adaptation Options**



1. *Pavement strengthening*: For low traffic volume road, unpaved pavement made of earth and gravel are prone to rapid deterioration due to soil moisture saturation from excess water. Hence, the pavement strengthening for low traffic volume option aims to create a more climate-resilient surface by investing in bitumen sealing or concrete paving, which increases the strength and protection of subsurface road conditions. The national target program of new rural development has a key objective of strengthening pavements and reducing the proportion of unpaved pavement for climate resilience. Periodic maintenance of the pavement to preserve its strengthening characteristics is an essential climate resilience action. Options for high traffic roads also should be improved for rutting resistance as well as anti-aging and fatigue cracking resistance by modified materials. Specific guidance of pavement structure design for high traffic volume road should be supplemented in current flexible pavement design standard. Temperature variation due to climate change should be considered for concrete pavement design and construction. Thermal stress and concrete slab length, curing duration and regime should be analyzed using the practical temperature data. Options of pavement materials for natural resource saving and reducing emission, such as using recycle materials, using cold or warm asphalt mix, also could be considered.

2. *Improved pavement drainage*: This is aimed at avoiding disruptive flooding and pooling of water and sediment on roads (or bridges). The investment also targets improving the road surface cross fall, putting in more side drains, turn-out drains, and scour checks. Maintenance should clear the drainage and prevent scour. Drainage pavement layer or drainage pavement structure using porous asphalt or porous concrete and drain base could be provided in the standards as optional solution, specifically in urban areas.

3. *Earthwork protection*: To prevent failure earthwork slopes, this investment option works by adopting different climate-resilient slope strengthening measures, including improved masonry and bioengineering standards (ADB 2017, Ref 1113) to enhance embankments and cut road slopes. Drainage systems for earthwork protection structures need to be strengthen using combination

of graded filter layer, cut-off drain, chute and cascade drain and transverse culvert. Periodic and routine maintenance of the slopes and drainage should remove loose materials.

4. *Riverbank slope protection*: Aimed specifically at enhancing climate-resilience of road slope structures adjacent to rivers. This option includes installing gabions, block facing, bio-engineering to strengthen slopes (ICEM 2017 Ref 1113), and improving face drainage against overtopping due to river flooding. Investment in slope strengthening can be undertaken with periodic maintenance. This intervention protects the roads against landslide disruptions. Drainage system for stabilized road slope also needs to be strengthen by the requirements in design standards and technical guidance similar as in earthwork projection. Periodic maintenance for the drainage is very important to ensure functions of the drains and stability of the slope. Many roads along river – stream are damaged by slip erosion or by toe erosion. Solutions of river – stream bank protection should be considered that involve a combination of engineering and bio-engineering solutions.

5. *Drainage Upgrade*: Drainage upgrade and improvement includes upgraded cross drainage (mainly culverts and bridges) and improved side drains system. This investment option builds more climate-resilient culverts/bridges and/or increases the size and protection standards of existing culverts and bridges (stream and relief), reflecting the increases in flood intensities due to climate change. Periodic maintenance of the culverts and bridges is performed to remove debris and sediments to prevent scouring. Flood vulnerability of culverts in Vietnam is a major issue, with several instances of the culvert and small bridge failures recorded during major flood events (CSCNDPC 2017).

5. *Coastal Bank protection*: Erosion and bank slip erosion is an important consideration for climate change in South – Centre and in the South regions. This investment provides various options for sea bank protection which combines between structural options of concrete block, concrete frame and rock, and bio-engineering of coastal mangrove forests. Coastal road system plan of Vietnam should be integrated with the forest protection and development.

6. To support transport infrastructure planning with a lower risk of potentially harmful environmental changes and reduction of the critical impact of climate change due to new infrastructure, analysis may increasingly need to be carried out using simulation tools and including climate change data. Solutions for infrastructure design can be made based on analyzed results.

5 The Vietnam Regulatory Framework for Climate Change Adaptation

Vietnam regulatory framework for climate change adaptation similarly with other professional issues includes relevant laws, decrees, circulars, and standards. In this section, only standards relating to roadworks are reviewed and assessed for sufficiency and appropriateness at climate change adaptation aspect for improvement proposal.

The most updated standard which could provide solid base for designing infrastructures approaches climate adaptation is 2021 draft version of the National Technical Regulation on Natural Physical & Climatic Data for Construction (QCVN 02:2021/BXD). It provides updated data (to around 2016-2017 of Vietnam climate includes critical climate and natural phenomenon. The updated climate data is provided by IMHEN (Vietnam Institute of Meteorology, Hydrology and Climate Change) which are consolidated from climate stations all over Vietnam. However, key road and bridge design standards mostly still have not updated for effective treatment solutions of climate change adaptation.

5.1 Road Design, Construction and Maintenance

Key road design standards that should be focused on are:

i) TCVN 4054:2005 - Highway – Specifications for design

ii) TCVN 5729:2012 - Expressway – Specifications for design

iii) TCXDVN 104:2007 – Urban road – Specification for design

iv) TCVN 10380:2014 - Rural Roads – Specifications for Design

v) TCVN 9845:2013 – Calculation of flood flow characteristics

vi) 22 TCN – 211 – 06 – Flexible Pavement Design Specification

vii) 22TCN – 263 – 2000 – Road Survey Specification

Road design standards in Vietnam are not updated to keep pace with changes in policy , conditions in general or climate changes. Key road design standards TCVN 4054:2005; 22 TCN – 211 – 06; and TCXD 104:2007 have been in use for about 15 years and climate changes are still not considered as a critical issue. Others have been in used nearly 10 years and do not officially make mention of climate adaptation. In these road design standards, there is no reference to flood protection standards. The urban road design standard (TCXD 104:2007) does not refer to the regulation on flood resistance for urban areas according to QCXDVN 01: 2008/BXD. The updated standard of National Technical Regulation – Technical Infrastructure Works – Transportation Infrastructure (QCVN 07-04:2016) and the National Technical Regulation – Technical Infrastructure Works – Drainage (QCVN 07-02:2016) has not mentioned in detailed for climate change adaptation.

While TCVN 4054:2005, article 10.6, Table 30 includes a note of "at the road sections crossing cities or residential areas, the designed road elevation is specified following fixed-elevation in urban planning and the flood frequency to calculate the drainage works and roadbeds according to urban design standards", there are no specific provisions in TCXDVN 104:2007 or in QCVN – 07 – 02,04 for the designed flood frequency but re-referred TCVN 4054:2005. Urban planning conforms flood protection standards. And it is difficult to find a connection between these road design standards and flood prevention standards.

Apart from regulations for standard design implementation, Vietnamese design consultants are not provided with legal support for data collection or design guidelines. Standard TCVN 9845:2013 (Article 5.2.1) prescribes the calculation of the peak flood discharge corresponding to the design frequency with the maximum daily rainfall parameter corresponding to the design frequency of the relevant hydro-meteorological station. Neither this standard or any other road design standard stipulates or gives legal procedures for hydrometeorological stations to provide rainfall data series for hydraulic analysis. There is also not any official guideline to process the raw rainfall data from stations, which could be different between each other depends on equipment and technology of the station, to estimate the maximum rainfall corresponding to the design frequency.

The design standards are semi-standard (with regulations on design principles), or semi-guideline (with specific provisions for cases). For example, there is a general requirement of Article 7.8.7 TCVN 4054: 2005 is: "The slope of the embankment must be reinforced by measures suitable to local hydrological and climatic conditions to prevent erosion caused by the impact of precipitation, currents, waves and flooding water level", but there also is another article 7.8.4 which is very specific case of "When the embankment slope is relatively high (8m to 10m high), a terrace should be created at width from 1.0m to 3.0m. The terrace should has sufficient cross-fall to cut-off paving drain. The road slope should be stabilized by using masonry or pre-casted concrete bricks". Such the specific article does not cover all actual conditions as well as technical solutions while the general article needs detailed design guideline or manual to support designers for design solution selection and calculation and analysis process. ; on the steps has a horizontal slope structure and a trench. In addition, high slope roofs should be reinforced with masonry or precast cement concrete slabs. To support the design standards, it would be necessary for a design guide to indicate various technical solutions of embankment stabilization and slope protection, their application, calculation and analysis procedure.

However, some any but not enough individual solutions are standardized, such as TCVN 9152 : 2012 - Hydraulic structures - Designing Process for Retaining Walls; TCVN 11823-11:2017 Highway bridge design specification – Part 11: Abutments, piers and walls; TCCS 13: 2016 – Gabions Gravity Retaining Wall – Specification for Design, Construction and Acceptance TCVN 10335:2014 - Gabions and Revetment Mattresses and double - Twisted hexagonal mesh Products used for Waterway Constructions – Specifications. However, these standards do not cover all types of embankment stabilization and slope protection.

The standards for surveying works (22TCN – 263 – 2000 or the updated standard of TCCS 31:2000) are both have not included specific provisions or guidance for data collection and analysis for climate change assessment or climate change impacts, climate change scenario recommended to forecast future data for using in the design instead of using history data to CCS design.

Standards are legal documents which must be followed, while guidelines can be flexibly applied to specific provisions included in the standard. Specific provisions that lack universality for all practical cases included in the standards can lead to inappropriate design. A very simple example is the specific value for cross-fall of road cross section depending only on surface material only without considering any other factors.

In summary, amendments to the Vietnam Regulatory Framework and road-related standards need to address the following:

1. Improve the regulatory framework by issuing of formal guidelines/circulars to support environmental-friendly infrastructure planning and support the application of new and innovative construction materials and construction methods, flexible design standards, and different approaches to design to ensure infrastructure can withstand the projected changes in climate.
2. Improve road design standards for climate change adaptation to stipulate the design input data incorporating climate change condition factors of increasing rainfall, critical storms and typhoon, flooding and flash flood, and SLR.
3. Update 22TCN 263:2000 regarding surveying works for topography, geology and hydrology for road design to collect data covering climate change condition, for example for hydrological surveys to assess the hydrological regime taking into consideration the additional rainfall under the climate change scenario.
4. Update TCVN 4054:2005, with supplemental articles on geometric design to ensure vertical alignment of embankment, cross-fall and super elevation for sufficient drainage and visibility in critical weather conditions; bioengineering options to reinforce embankment, to protect road slope, to block wind and sand; and planting and restoring mangrove forests to break waves.
5. Update standard of flexible pavement structure design, develop standard of rigid pavement design with stipulations on the selection of pavement structures using appropriate layer materials to withstand weather condition. Update also to provide appropriate calculation and analysis of selected pavement structures which takes into account climate change impact factors.
6. Update road design standards (of expressway, urban road, rural road) to strengthen flood and storm prevention to minimize the negative impacts of weather.
7. Provide road construction/maintenance standards of innovative road engineering materials and technologies for longer life of road and encouraging environment friendly construction solutions, such as recycling, waste materials utilization and/or low emission technologies.
8. Update road maintenance norm/standards to provide a basis for climate change adaptation road maintenance planning.

Details of review and recommendations for strengthening road design standard to adapt climate change conditions are in Annex C, Table C 1.

5.2 Bridge Design, Construction and Maintenance

As regards Road Bridge Design Standards published in 2017, the following contents summarize the standard construction principles, specifically as to converting and upgrading the industry standard 22TCN 272-05 Bridge design standard into National Standard – Highway Design Standard.

The updated contents are compiled from the original AASHTO LRFD Bridge Design Specification, SI Unit, 4th Edition, 2007 (hereinafter referred to as AASHTO 2007). Compiling only the content of the provisions, not compiling the comment as standard 22 TCN-272-05. Except for some articles with new technical content, more detailed is added as an explanation of the original version to facilitate understanding and easy application for Vietnamese engineers.

1. Keep the chapter numbers as of the original AASHTO 2007
2. Do not compile Part 7- Aluminium structure and Part 8- Wood structure as standard 22TCN 272-05 has done, because Vietnam does not actually use it.
3. Terms have been updated in the 6th edition of the AASHTO Standards (2012), the foundation of AASHTO's 7th edition (2014) with more concise, understandable wording.
4. The details of wind load calculation are kept as specified in 22TCN 272-05 because this calculation is based on the wind conditions of each region, not according to the original calculation of wind pressure common to all regions of the AASHTO versions.
5. The navigability standard is kept the same as the concept of standard 22 TCN 272-05, but the concept of navigable water level is according to the new in-land waterway standard TCVN 5664 - 2009.
6. Ship collision load according to the original AASHTO collision probability concepts. This will require a guide to make take account size of in-land waterway ships in Vietnam
7. The earthquake calculation method remains the same as the original version of AASHTO 2007 and is not updated according to the 2012 versions because the seismic acceleration partition map follows Vietnam's anti-seismic design standards.

The bridge design standard inherits the American standards and is upgraded from the current standard 22 TCN 272-05. It can be seen in the standard description that the content related to the effects of climate change mentioned will focus on item (1) This calculation is based on the actual wind of each region; (2) The navigable water level according to the new riverway standard TCVN 5664 - 2009; (3) Factors affecting climate need to be considered such as temperature, rainfall, etc.

As a general comment it should be noted that standards involving climate data and related hydrological data should require the use of **assessed future data** rather than being totally dependent on **historic data**. This time frame of this future climate data should be compatible with the design life of the road asset being considered, for example around 15 years for a road pavement or 100years or more for a large bridge.

The research team approached on the basis of a summary of the changes of AASHTO 2007 compared to the version of AASHTO 1998 (the base version for the compilation of the 22TCN 272-05 standard) and the new updates of the AASHTO 2012 versions with some updates in January 2015. Reviews, comments and suggestions are all adjusted and detailed in Annex C, Table C 2.

6 Good Practice for Climate Change Adaptation for Road Networks

6.1 General

Following-on from the review of the MP and SER documents, good practices for local planning are summarized in Table 6.1 (*Source: Local planning for climate adaptation: Vietnam's experience, Asian Cities Climate Resilience, Working Paper Series 24: 2015*). These suggestions could be integrated in road network planning and/or road works planning to provide sufficient climate adaptation measure.

TABLE 6.1. **Good Practice for Climate Action Plans (CAP)in Road Network Planning**

Good Practice	Description
Coordination by local staff with external technical inputs.	The CAP process is coordinated by local government staff with technical support from external experts as required.
Departments involved in implementation.	Key technical departments involved in implementing plans are also part of the planning team.
Interaction/collaboration between technical specialists, departments, services.	Formal collaboration and consultation mechanisms exist to ensure that different technical departments, specialists and government service units can review and comment on the draft plan.
Consultation with vulnerable community groups.	Social groups who are most vulnerable to climate impacts are specifically involved in consultations to assess vulnerability, risk and alternative adaptation measures.
Responsibility for implementation assigned.	Clear responsibility for implementation of CAP recommendations is assigned to specific agencies
Iterative process (shared learning)	The CAP process is iterative: some parts of the process have been repeated as information improves, lessons are widely shared and documented and feedback is provided to contributors.
Local commitment.	Local political commitment to the CAP process is high, as demonstrated by executive-level support.
Driven by local interest.	CAP procedures and priorities are driven by local context and respond to locally determined priorities.
Experience driven by international donor.	The planning process responds to advice from international donors and their technical experts and to priorities they have identified.
Request for additional information.	Local planners request additional information from external expert consultants, national government or other local departments to respond to emerging issues as the plan develops.
Prioritization of adaptation measures.	The CAP establishes a limited number of priority measures for implementation.
Recommendations focus on key vulnerabilities	The priority recommendations respond clearly to vulnerabilities identified in the plan.

Good Practice	Description
Implementation of recommendations.	Priority recommendations in the original CAP are implemented by local government.
Recommendations supported by implementing agency.	The CAP recommendations are reviewed and approved by the technical departments responsible for their implementation.
Financing of implementation measures.	Financial resources for implementation are identified in the CAP.
Barriers/incentives to implementation.	The CAP explicitly identifies any notable barriers or incentives that could prevent or support implementation of recommendations
Monitoring	The CAP includes mechanisms for monitoring implementation and updating the plan.
Use of best available science.	Climate change adaptation planning uses the most recent available climate projections, including estimates of uncertainty.
Availability of climate information.	Climate information has been made available to the public as part of the planning and consultation process.
Assessment of climate impacts.	Climate projections have been used to assess likely impacts from climate change.
Application of hydrological models.	Hydrological modelling has been applied to assess risks of flooding from rivers or sea-level rise.
Vulnerability assessment	A formal vulnerability assessment has been undertaken to demonstrate which groups and sites are most vulnerable to climate impacts
Risk assessment.	A formal risk assessment has been undertaken, either quantitative or qualitative, explicitly assessing the probability and magnitude of damage from climate impacts.
Risk assessment used in prioritization	Conclusions from risk assessment have been explicitly used in determining priorities for adaptation recommendations.

6.2 Adaptation Measures: International Guidance, Best Practices, Experience

TA group reviews a number of additional international documents with a view to identifying a key best practice approach (*Iraklis Stamos, Evangelos Mitsakis, Josep Maria Salanova Grau. Roadmaps for Adaptation Measures of Transportation to Climate Change. Transportation Research Record Journal of the Transportation Research Board 2532(1):1-12, Sep 2015*) with 06 solution group. Brief summary of the measures provided in the reference are extracted as follows from section 6.2.1 to 6.2.6 and Figure 6.1. Based on the practice approach, a number key measures are proposed in Vietnam context which are discussed in Chapter 8.

6.2.1. Organizational and Decision-Making Processes

Measure A1. Setting and implementation of international standards for weather and emergency information.

Measure A2. Consultation with and coordination of highway authorities, subcontractors, suppliers, and key stakeholders to adjust adaptation strategies.

Measure A3. Establishment of networks of urban, regional, and national stakeholders, transport companies, authorities, and users.

Measure A4. Dissemination of educational and information material on emergency cases, planning, and maintenance to related authorities.

Measure A5. Conduct public campaigns in order to raise public awareness regarding local hazard situations.

6.2.2. Technical Options

Measure B1. Construction of dikes and creation of flood barriers for protection against water.

Measure B2. Innovative pavement materials resistant to corrosion.

Measure B3. Improved drainage system

Measure B4. Elevation of coastal road networks.

Measure B5. Design of and investment in new assets with ''quick restoration" capability.

Measure B6. Provision of shelters for nonmotorized transport.

Measure B7. Preparation for sufficient road clearing equipment availability before and during winter or storm seasons.

Measure B8. Development of timely communication and coordination plans involving stakeholders and freight operator associations.

Measure B9. Roadside vegetation, absorbing generated heat, protecting roads.

Measure B10. Design of new heat-resistant asphalt mixes.

Measure B11. More heat-resilient bridge joints.

Measure B12. Need for improvement of drainage-sewer systems..

Measure B13. New asphalt mixes help in faster drainage of standing water.

Measure B14. Enhancement of road layers..

Measure B15. Measures of protection against slope subsidence around road/rail network to avoid cut-off links.

Measure B16. Additional pumping in tunnels.

Measure B17. Installation of windbreaks.

Measure B18. New design standards relating to components of the road network (signs, lighting) enhance users' protection.

6.2.3. Procedural and Operational Options

Measure C1. Organization for the supply of trapped drivers/passengers with the help of volunteers and aid organizations.

Measure C2. Adaptation of timetables and service intensities under adverse weather conditions.

Measure C3. Need for alternate routes for freight transport.

Measure C4. Priority plans that maintain access to hospitals and emergency stations.

Measure C5. Definition of priority routes for road clearance in case of large-scale impacts.

Measure C6. Tracking of "chain reactions" of extreme weather events, particularly in agglomeration areas.

Measure C7. Coordination of emergency plans among transport modes and networks.

Measure C8. Iimplementation of appropriate risk management procedures in order to be prepared for adverse conditions.

6.2.4. Information Flow and ICT Support

Measure D1. Development of sustainable business models for the provision of emergency information systems.

Measure D2. Provision of reliable, instant, and—if feasible—personalized information on the duration a climate related incident and travel options.

Measure D3. Installation of signs that warn the driver on the upcoming pedestrian flooded network.

Measure D4. Development of intelligent feedback systems in vehicles to communicate user needs.

Measure D5. Adopted operational, physical, technical, procedural, and institutional integration of weather and traffic control services.

Measure D6. Preparation and broad communication on disruptions and alternatives with the public, using a variety of communication channels.

Measure D7. Standardization of weather information and hazard warnings.

6.2.5. Decision and Risk Models

Measure E1. Provision of cost-benefit assessment guidelines to logistics companies.

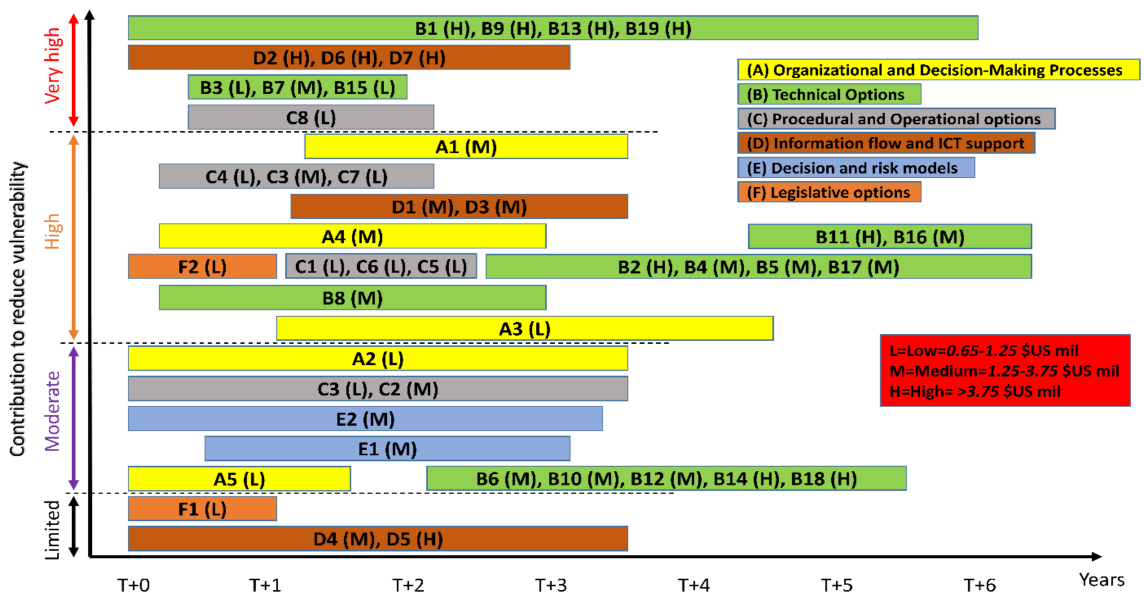
Measure E2. Assessment of logistics companies' risk exposure and establishment of appropriate adaptation plans.

6.2.6. Legislative Options

Measure F1. Strict speed limit enforcement during storms.

Measure F2. Review of maintenance contracts and procedures to make them flexible and effective even under rapidly changing weather conditions.

FIGURE 6.1. **Roadmap of Adaptation Measures in literature**



7 Lessons learnt from road transport project program for climate change adaptation

7.1 National and local road network development planning

Law of Environment Protection No. 72/2020/QH14 requires for national, regional and provincial development sectorial strategy, master plans and plans, such as transport development planning, must be assessed for environment impacts. Key three among ten required contents follows Circular No.27/2015/TT-BTNMT dated 29th May 2015 – Appendix 1.3 are:

- Assess the suitability the sectorial strategy, master plans and plans with viewpoints and objectives of environment protection.
- Assess and forecast environmental issues while the sectorial strategy, master plans and plans are under implementation.
- Assess and forecast impacts of climate change during implementation of the sectorial strategy, master plans and plans.

The question how the national and/or local road network development plans adapt to climate change condition still has not clear in the legal documents or in any guidelines of sectorial plans. A good climate change adaption plan helps decision makers having sufficiently clear viewpoint of appropriate and economic solutions.

From review the Master Road Network Plan and NDC report, it was found that technical solutions of climate change adaptation are not clearly presented in the Master Planning. A guideline which is under legal document as circular for planning implementation covers climate change adaptation is necessary.

7.2 Typical current WB road projects and program in Vietnam

7.2.1. VRAMP (Vietnam Road Asset Management Project)

VRAMP was approved and commenced in December 2013 then restructured in 2019 and 2020 for national road improvement and national road asset management software. The project originally and especially at restructure period provides priority to national roads which are under critical climate change condition. NH6 and NH2 in North Mountain Area, and NH9 in central region are selected for improvement will strengthen these roads themselves and national road network for climate change adaptation. Design solutions for climate change adaption were not clear due to non-updated legal standard results to difficulties during approving progress.

VRAMs has been built for national road network management. However, natural factors or climate change conditions still has not considered as input data for the road management progress using VRAMs. Road maintenance planning based on traffic document rather than natural condition.

7.2.2. LRAMP (Local Road Asset Management Programme)

LRAMP was approved and commenced in 2016 with priority to the areas impacted mostly by climate change in Vietnam. 14 provinces are selected under road program are in the North Mountain and Central Region. 50 provinces are under bridge program give priority to bridges' selection in remote areas impacted by climate change condition.

Under LRAMP, a TA service of climate resilience was provided to support civil works of road improvement and bridge construction. A set of guidelines for climate change adaptation includes: climate change vulnerability assessment for local road; hydrological analysis for local road and bridge design; technical measures for local road and bridge design for climate change adaptation; technical measures of local road maintenance for climate change adaptation; Priorities in management, planning and assessment of climate change adaptation measurements. However, it is found that the TA products are less applicable due to itself applicability as well as limitation of institutional frame because of non-updated standard system.

LRAMs still is on-going further development with objective points of G-VPROMP for geo-spatial road network management and G-CBA for geo-spatial road maintenance planning integrated priority criteria of impacted climate factor. LRAMs when completed could provide effective tools for road management and maintenance of climate change adaptation.

7.2.3. CHCIP (Central Highland Connectivity Improvement Project)

CHCIP original objectives cover climate change adaptation. A team of climate change adaptation has been mobilized for controlling climate change adaptation at design stages. Recommendations have been provided by climate change international and local experts at preliminary and technical solutions comparison and selection, and at detailed design stage. Working paper 9 of the Short Note on Climate Resilience Options for NH19 Priority Section is an example of the road design solution for climate change adaptation.

However, similar with other projects, proposal of design solutions for climate change adaptation were limited by the institutional system of non-updated standards and limited budget.

7.3 Typical road planning and road projects under domestic fund

The most typical local road plan is North – South expressway. During development of the North – South expressway plan, floods at the central region was analyzed concurrently with consistency between the longitudinal routes of NH No.14, the North – South expressway, the North – South railway and the existing NH. No.1A. It was found that Thong Nhat railway causes severe flooding upstream due to limited drainage capacity of the old drainage structures on the railways.

During NH1 upgrade project preparation, a hydrological modelling (NAM model) and hydraulic analysis tool (MIKE 11) was used for flood analyses and technical solutions comparison and selection. The analysis results help technical appraisal for feasibility study and design alternative selection.

Experience from many road projects under local state budget show inadequacy of hydrological survey for road design.

The shortcomings of surveying work for hydraulic calculation and analysis are at:

- Preparation prior surveying works to collect meteorological and hydrological data from available documents for historical flood levels.
- Poor hydrological investigation results to incorrect flooding appearance year and inaccurate hydraulic calculation and analysis
- Inappropriate selection of location for hydrological investigation results to unreliable data and confusing historical flood levels
- Hydrological survey as in current standard required only historical flooding water level, but not: causes of the flood and flood evolution; characteristic of flooding flow with falling rocks, fallen trees or mud; influence if any of tidal flow; erosion at upstream and downstream; overflow at downstream which could make hydraulic analysis short-sighted.
- Hydrological survey along flooded road section as in current standard also required only flooded water level, but not: flooding duration and traffic interruption duration; flood depth; location and direction of overflowing and subjectively estimated overflow of swift-flowing, medium or calm flowing compared with erosion and/or landslide occurrence.
- There is not specific guidance for hydrological survey at typical terrain, for example of mountainous to require flow characteristic with rolling rocks and mud, or of flat at river mouth to require tidal flow direction and frequency.
- Hydrographic engineer and functional tasks of surveying to collect necessary data for hydrological modelling and hydraulic calculation and analysis, providing the analyses and controlling reliability of the collected data rarely are required as key and separated person in a transport project.

8 Adaptation Measures in the Vietnam Context

8.1 General

The proposed roadmap issues, as listed above, have been summarized from international studies. These issues must be assessed and adapted for use in the specific climate change and road regulatory frameworks in Vietnam. This and the following section proposes revised adaptation measures in the Vietnam context which integrate from output of Vietnam road and bridge standards review and experience and lessons to be learnt from transportation infrastructure development projects.

8.2 Organizational and Decision-Making Processes

Measure A1 requires a review and systematic investigation of international standards. This provides challenges of availability and adaptation to Vietnamese standards. It would require a longer review process to adopt fully these standards into the Vietnamese context. However, key standards could be selected to implement in short-term to establish basic legal frame of road transport sector for climate change adaptation. These studies could be in the form of a Technical Assistant (TA) to help the Ministry of Transport (MOT) and other ministries to achieve relevant outputs.

Measure A2, A3 require exchanges with the authorities, stakeholders, companies. Given that the awareness of climate change consequences in Vietnam is an initial stage, these tasks would be more difficult some stakeholders than others. The contribution to reducing the vulnerability is rated Very High in this case due to changing institution system.

Measure A5 is critical to raise public awareness regarding local hazard situations. However, the contribution to reducing the vulnerability is rated High. For this particular measure, in Vietnam, it is suggested to conduct in short term period.

Measure A6 is additionally proposed to create legal corridor to support decision makers during review and approval process for climate adaptation transportation infrastructure. Selected standards have been reviewed under this TA to find specific issues should be improved for climate adaptation. Measure 6 is divided in 05 sub-measures relating to selected standards for revision in short-term which are all in Very High rate of vulnerability reduction. In short-term of 5 years, A6-1,3,5 are suggested for urgently implementing within 02 first year and the others of A6-2,4 are later urgent required.

TABLE 8.1. **Measures of A. Organizational and Decision-Making Processes**

Measure	Description
A1	Setting and implementation of international standards for weather and emergency information.
A2	Consultation with and coordination of highway authorities and key stakeholders for climate adaptation strategies and adaptation strategy adjustment
A3	Establishment of networks of transport companies, management authorities, and users at national, regional and urban level for implementation of adaptation strategies.
A4	Dissemination of educational and information material on emergency cases, planning, and maintenance to related authorities.
A5	Conduct public campaigns in order to raise public awareness regarding local hazard situations.
A6	Improving and supplement of national technical standards system for climate adaptation transport infrastructure

Measure A6 should focus on the key road and bridge standards and relevant technical guidelines which are under review and proposed by TA team. The details are presented in Table 8.2

TABLE 8.2. **Sub-measures of A6 – Revise, supplement and develop road and bridge standards and relevant technical guidelines for climate change adaptation**

Measures	Description
A6-1	Improve TCN existing standards to the national standards or update currently relevant professional specification to incorporate climate change adaptation: i) 22TCN – 211 – 06 – Flexible Pavement Design Specification ii) 22TCN – 263 – 2000 – Road Survey Specification; TCCS 31: 2020 – Highway – Specification for Survey iii) 22TCN 356:2006 – Modified polymer hot asphalt mix – Construction and quality control
A6-2	Improve/update design standards of road and bridge for climate change adaptation: i) TCVN 4054:2005 - Highway - Specifications for design ii) TCXD 104:2007 – Urban roads – Specification for design; QCVN 07- 4: 2016 – National Technical Regulation of Transportation Infrastructure iii) TCVN 10380:2014 – Rural roads – Specification for design iv) TCVN 9845: 2013 Calculation of flood flow characteristics corresponds QCVN 02: 2021/BXD – Natural Physical and Climate Data for Construction
A6-3	Improve road construction and maintenance standards for climate change adaptation: i) TCVN 9436 : 2012 - Highway embankments and cuttings – Construction and quality control ii) TCVN 8819: 2011 – Hot Asphalt Mix – Construction and quality control iii) TCCS 07: 2013 – Road routine maintenance specification iv) Norm of Road Routine Maintenance under No.3479: 2014 Decision
A6-4	Develop road standards of new construction materials and technologies based on available research outputs: i) Recycling and waste materials ii) Low emission construction material and technology
A6-5	Develop Technical Guideline of Environment-based and Climate Change Adaptation Road Design.

8.3 Technical Options

For adaptation in Vietnam context, the technical options could be divided in 04 groups for analyzing to apply and/or modify and supplement.

Group 1 includes measures relating to road network development and rehabilitation planning (B1, B4, and B5), which are renamed B1-1, B1-2 and B1-3;

TABLE 8.3. **Measures of planning of B-1 Technical Options**

Measure	Description
B1-1	Create flood barriers system and emergency roads follow flood protection standards
B1-2	Coastal road networks planning with appropriate elevation
B1-3	Design of and investment in new assets with "quick restoration" capability

Measure B1-1 must be carefully considered, especially in the South and coastal areas of Vietnam (including Ho Chi Minh city). The priority list for the construction of dikes must be first analyzed, following by the financial plan for the proposed activities. This could require a long process of implementation.

Measure B1-2 is rated as a moderate contribution to reducing the vulnerability within both medium and long term in Vietnam.

Measure B1-3 could be considered for extremely high risk of climate change impacted areas. Methodology of designing "quick restoration" structures must be clearly approached. The new "quick restoration" assets will be included in the road maintenance planning.

Group 2 relates to road drainage improvement (B3, B12, B13, and B16) which are renamed from B2-1 to B2-4;

TABLE 8.4. **Measures drainage improvement of B. Technical Options**

Measure	Description
B2-1	Establish plan and implementation the plan for improving drainage structures on key transport corridors
B2-2	Improve drainage systems include side and road slope drains on national, local road networks and urban roads
B2-3	Drainage pavement structure (of porous asphalt or cement concrete and base) to help in faster drainage of standing water
B2-4	Strengthen drainage by pumping stations for underground structures such as tunnels and in urban areas.

The measures of drainage improvement (Group 2) are necessary for the current Vietnam road network, specifically for local road network where the drainage system commonly is insufficient due to limited budget. Ineffective drainage system also could be found in many roads even in high standard road. Less maintenance is major issue, but inappropriate design and under-design compared with climate condition is a common cause of the ineffective drains. Improvement of drainage system should be considered as major as pavement improvement of individual road rehabilitation project.

Requirements for an appropriate and sufficient drainage system should be provided in the updated road design standards as detailed in Table C.1 Annex C. Technical solutions for a comprehensive drainage system should be provided in guidelines, from simple side drains, to moderate complicated of earthwork drains multi- culverts.

Measures in B2 group are applicable in Vietnam, with the appropriate timing and cost. B2-2 measure is long-term progress which could be integrated in medium term investment and/or expenditure plans of road rehabilitation and maintenance works. Prioritization should be provided to the key transport corridor for national and urban road network and to higher RAI local roads. B2-3 should be provided to high speed roads for traffic safety and urban roads to support drainage system to reduce flooding period.

Group 3 covers measures of innovation construction materials and technologies for being better road performance in climate change condition and/or lower emission (B2, B9, B10, B11, B14, B15, and B17 as in original international documents) which also revised and renamed in order from B3-1 to B3-7;

TABLE 8.5. **Measures of innovation construction materials and technologies of B. Technical Options**

Measure	Description
B3-1	Innovative pavement materials resistant to weathering and enhancement of pavement layers for durability at hard weathers
B3-2	Roadside vegetation and bio-engineering solutions for absorbing generated heat and road slope protection.
B3-3	Apply new heat-resistant asphalt mixtures
B3-4	Apply recycling materials for road and pavement construction
B3-5	More heat-resilient bridge joints
B3-6	Measures of protection against slope subsidence around road/rail network to avoid cut-off links
B3-7	Installation of windbreaks or breakwaters structures on appropriate sections of roads and railways

Measures B3-1, B3-3 are rated High in applying to Vietnam, especially for the central region. For B3-3, many MoT-supported research projects have been carried for standardization modified bitumen (PMB) and AC using modified bitumen (BTNP) for anti-rutting pavement. Temporary technical guidelines of high friction asphalt course and porous asphalt for surfacing layer have been issued. The necessity of update and improvement of current construction standards (TCNs) and issue of the formal standard is discussed in Annex C – Table C.1. Beside PMB, BTNP and high friction, porous, many other technical solutions of innovative materials for improving durability of the asphalt pavement have been researched for project applicability and innovative technologies of pavement recycling have been focused on reducing natural material sources utilization. Asphalt pavement recycling has been applied in Vietnam and needs formally standardized. B3-2 and B3-4 measures help reduce emission due to reduce natural resources exploitation and cement utilization. Measures B3-2 requires a lengthy implementation time in Vietnam. Measure B3-6 should be placed on medium-term implementation and Very High contribution. They also create green roads which lower emission due to reduce cement uses. B3-4 should be placed in short term although it has moderate contribution to vulnerability reduction due to asphalt pavement recycling and auxiliary industrial production have been applied in road construction project under domestic budget.

Group 4 are measures road transportation operation and road maintenance (B6; B7; B8 and B18) corresponds to new names of from B4-1 to B4-3

TABLE 8.6. **Measures of road operation and maintenance of B.4 Technical Options**

Measure	Description
B4-1	Development of timely communication and coordination plans involving stakeholders and freight operator associations for potential "green" transportation flows during extreme weather conditions.
B4-2	Develop technical specification and norm for road routine and emergency maintenance considering climate change vulnerable areas.
B4-3	Strengthen capacity of road maintenance management and maintenance authorities and/or requirement for strong capacity of road maintenance management and maintenance contractors to have sufficient equipment for emergency maintenance during storm season.
B4-4	Provision of road user protection facilities, especially for vulnerable non-motorised road users, during extreme weather conditions includes design standards for road user protection facilities.

Measures B4-2, and B4-3 are at Very High rate of road climate resilience and applicable in Vietnam, with the appropriate timing and cost. They should be at high priority for implementation in short-term. Climate vulnerability zoning could help revise norm of road routine and emergency maintenance, then followed by technical specification. The sufficient regime of road maintenance based on climate vulnerable level is legal support for capacity strengthening of the road management and maintenance authorities and contractors. B4-1 needs to be combined with the road network planning for providing the potential "green" road for capably being opened in the extreme weather condition. The road network planning should be combined with the transportation flows planning and maintaining. B4-1 measure is at High rate for climate resilient to be implemented in medium term. Measure B4-4 are challenging to achieve in Vietnam due to there are limited roads for nonmotorized transport in Vietnam. However, this measure encourages non-motorised transportation, then helps to reduce emissions.

8.4 Procedural and Operational Options

Measures of procedural and operational options fully follows international practice as in Table 8.7 with adjustments of applicable period.

TABLE 8.7. **Procedural and Operational Options**

Measure	Description
C1	Organization for the supply of trapped drivers/passengers with the help of volunteers and aid organizations
C2	Adaptation of timetables and service intensities under adverse weather conditions
C3	Need for alternate routes for freight transport and for emergency roads
C4	Priority plans that maintain access to hospitals and emergency stations
C5	Definition of priority routes for road clearance in case of large-scale impacts
C6	Tracking of "chain reactions" of extreme weather events, particularly in agglomeration areas
C7	Coordination of emergency plans among transport modes and networks
C8	Iimplementation of appropriate risk management procedures in order to be prepared for adverse conditions

Measures C1, C4, C5, C6 are more urgent due to more serious and higher frequency of extreme climate events occurring in Vietnam. They are at High rate of vulnerability reduction due to capably to provide effective responses during extreme climate events, and in high priority for implementation in short term. Measure C1 should be carefully considered, as Vietnamese authorities might not fully familiar with this type of measure.

Measures C3 and C7 is considered applicable in Vietnam combining with master transport network planning which includes multi- transport modes to provide effective transportation during the extreme climate events. They are at Moderate rate of vulnerability reduction and need further time to be implemented in the medium term.

Measures C2 and C8 should take advantage of international experiences to develop the process, plans, as well as priority plans to deal with extreme weather events. Several TAs or research projects could also be conducted to strengthen the awareness/knowledge of the Vietnamese authorities/ stakeholders. They are also assessed at Moderate rate of vulnerability reduction with longer time in long-term implementation.

8.5 Information Flow and ICT Support

IT measures help rapidly relying and responding to climate change conditions as well as during extreme climate events. These measures provide necessary and sufficient conditions to success of other measures. All D measures (from D1 to D8) are at Very High rate for vulnerability reduction.

Rapid development of IT in Vietnam provides highly potential application IT measures in transport sector. All D measures (D1 to D8) are potentially and successfully applied in 10-year of short and medium term. The measures of D5, D6, D7, D8 help road traffic safety increase in existing road networks should be in more priority which could be started in early period (short term).

The remaining measures of D1, D2, D3, D4 are challenging to apply in Vietnam in terms of Information Technology. These could need more time in medium-term orientation measures but must go along with the digital transformation process in Vietnam. However, with a medium to high implementation cost, these measures are suggested to perform firstly in expressway network which is on-going development. In the later stage of the roadmap, ITS application in urban areas and in the arterial national routes, specifically in highly climate vulnerable section.

Measure D6 of preparation and broad communication on disruptions and alternatives with the public, using a variety of communication channels has been started in Vietnam for traffic congestion information in big cities. Similar methodology should be used for warning extreme climate information to road users.

Measure D7 should be developed with cooperation between MOT (DOST, DTS), MIC, MARD and MONRE. Measure D8 is proposed to supplement by TA team for monitoring and dangerous warning system on the section roads which are under highly vulnerable climate change impacts.

TABLE 8.8. **Measures D of Information Technology and ICT Supports**

Measure	Description
D1	Development of sustainable business models for the provision of emergency information systems
D2	Provision of reliable, instant, and—if feasible—personalized information on the duration a climate related incident and travel options
D3	Installation of ITS system includes weather condition monitoring and signs and/or dynamic signs that warn the driver on the extreme weather conditions
D4	Development of intelligent feedback systems in vehicles to communicate user needs
D5	Adopted operational, physical, technical, procedural, and institutional integration of weather and traffic control services
D6	Preparation and broad communication on disruptions and alternatives with the public, using a variety of communication channels
D7	Standardization of weather information and hazard warnings
D8	Install monitoring and warning systems for transport structures at highly climate vulnerable section such as landslide, flood, flash flood,…

8.6 Decision and Risk Models

Measures from E1 to E6 could be short term measures with several TAs or research projects at MOT's level.

TABLE 8.9. **Measures E of Decision and Risk Models**

Measure	Description
E1	Provision of detailed implementation and budgeting program follows 2021 – 2025 Action Plan of MoT
E2	Provision of guideline for transportation infrastructure development planning to integrate climate change adaptation follows 2021 – 2025 Action Plan of MoT1
E3	Provision of guideline for Strategic Environment Assessment for transportation infrastructure development plans
E4	Provision of guideline for multi-criteria priority assessment for road works selection includes climate change vulnerability index and accessibility in emergencies
E5	Assessment of extreme climate factors exposure of transportation infrastructures to support appropriate adaptation plans
E6	Provision of cost-benefit assessment guidelines to logistics companies for transportation mode selection for climate adaptation

All of the measures of Decision and Risk Models are suitable to current situation in Vietnam. These should be implemented under TAs using national funds of science and technology or international grant trust funds.

8.7 Legislative Options

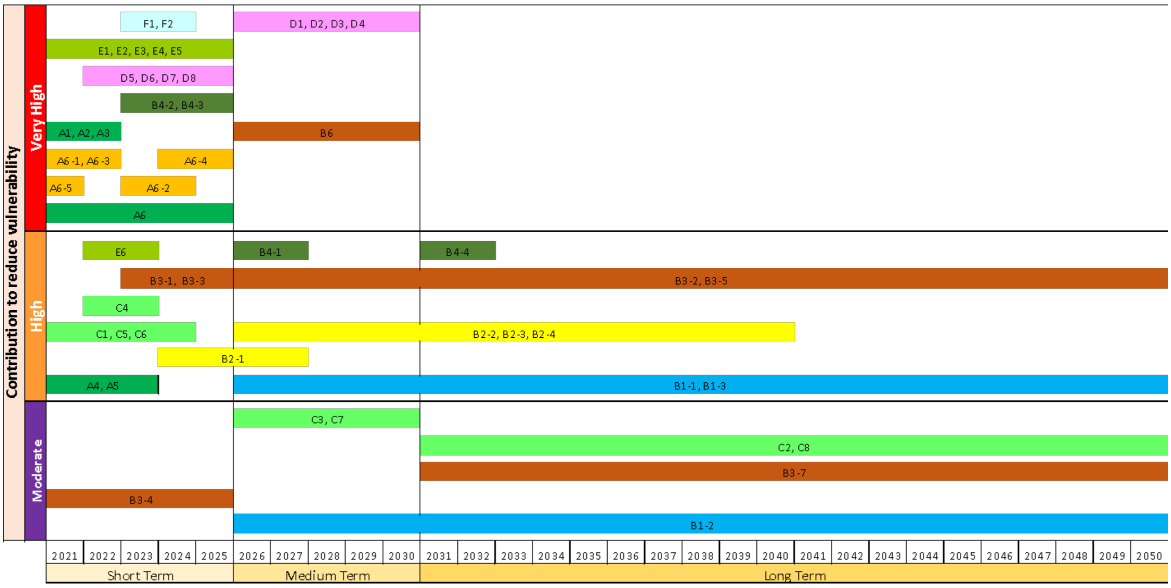
Measures F1 and F2 could be a short-term perspective. Both are rated Very High contribution and potentially applied in short-term.

TABLE 8.10. **Measures F of Legislative Options**

Measure	Description
F1	Provision of traffic control and management during extreme climate condition to national standard (QCVN 41:2019) integrate ITS for climate monitoring, such as strict speed limit enforcement during storms using VMS.
F2	Review of maintenance contracts and procedures for the flexible and effective contracting system under climate change conditions

Summary of discussion on the measures for contribution level to climate change vulnerability reduction and potential implementation in short term (5-year period), medium term (10-year period) and long term (30-year period) are presented in Figure 8.1.

FIGURE 8.1. **Outline program for proposed measures implementation**



9 Summary of Experience on Updating Standards

Incentives to include climate adaptation in programmes or individual projects are shaped by the policy and the regulatory environment (Standards, Decrees, Guides, Specification). Governments or individual Ministries can facilitate climate-resilient infrastructure by removing policy or regulatory constraints, or by adding regulatory requirements to consider climate risks and facilitate adaptation uptake (OECD, 2017).

The review process has been initiated under this TA and a number of recommendations for the updating or amendment of for the Vietnam road-sector regulatory framework have been identified and, although this should be an ongoing exercise, an interim list of general priority areas to be addressed is presented in Table 9.1

TABLE 9.1. **Regulatory Amendment**

General Priority Areas	Amendments/Additions
Climate Resilience Policy	Road network to be planned, design, constructed and maintained to defined climate resilient levels.
Climate Resilience Planning and Costing	Climate resilience to be a mandatory consideration in all national, provincial, local plans.
Project Life Cycle	Climate resilience should be a mandatory consideration on all stages of the project or road life cycle: Planning, Feasibility, Design, Construction and Maintenance.
Climate Change Data	For relevant standards, future climate and hydrological data to be used rather than historical data. Time span of data to be in line with design life of individual assets.
Climate Resilience Adaptation Measures	Individual road asset design standards and associated cost norms to be amended to take account of climate change issues: for example: • Pavement (sides drainage/erosion) • Alignment geometry – above flood levels • Bridge deck levels • Earthwork slopes/benches/drainage • Use of Bioengineering • Materials (strength/resistance to soaking) • Safety (landslide/flood warnings) • Drainage structures (Drains, Culverts, Bridges,…) with sufficient capacity & appropriately sustainable structures
Maintenance Planning and Implementation	Climate vulnerability and consequent resilience adaptation included in all maintenance planning models together with any require adjustment to maintenance method and norms.
Climate Resilience Monitoring and Evaluation	Inclusion of climate resilience monitoring and evaluation for all major projects (National, Provincial, Local) includes effectiveness of adaptation measures and actual climate records.

10 Ways Forward

The ReCAP 2019 Climate Change Management Guidelines (Ref 1177) identified a series of steps required for updating standards and design guides to take account of climate adaptations:

1. Review all existing standards, guides, manuals and similar publications/documents to determine whether climate threats and associated adaptation are adequately covered.

2. Determine which documents are being updated (or are soon to be updated) and initiate actions to incorporate adaptation in their Terms of Reference.

3. For those with no immediate plans to update, decide whether to bring forward the update or whether to produce some form of augmentation.

4. Form a multidisciplinary/multisector working group (or groups) to scope out and deliver the necessary adaptation augmentation requirements based on the prioritization set out above.

An essential key 1st step is recommended (Table 8.2), and an adaptation workshop with the following key objectives:

1. Policy-planning issues

2. Regulatory framework issues

3. Engineering adaptation

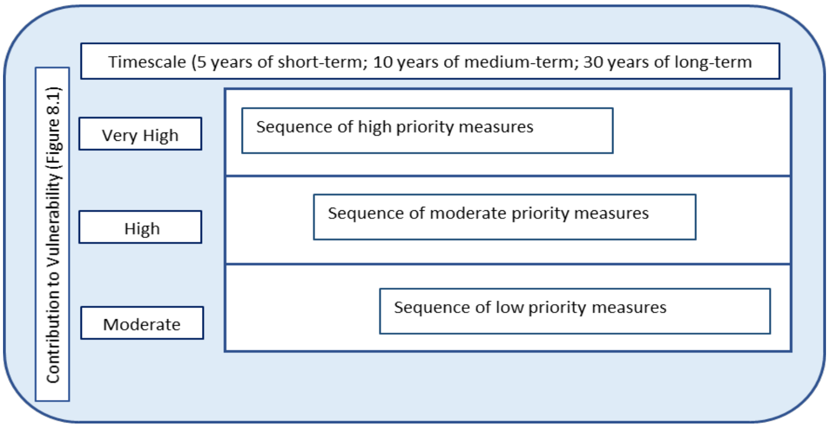
4. Non-engineering adaptation

5. Challenges to embedment

6. Way forward identified

The workshop should initiate detailed discussions on the way forward. This could be based around the measures discussed in Chapter 8 so that the proposed roadmap can detail the order that needs to be followed to enhance the resilience of Vietnam road transport system and reduce their vulnerability to climate change impacts.

FIGURE 10.1. **Presents proposed outline program for measures implementation**



Key standards under review for necessity of update and improvement are proposed in short term for road climate change adaptation. Summary of the proposed standard updates and mapping are summarized in Table 10.1

TABLE 10.1. **Road standards for update and improvement in short term (5-year) to 2025**

Ord.	Standard	Road Mapping
1	22TCN – 211 – 06 – Flexible Pavement Design Specification 22TCN – 263 – 2000 – Road Survey Specification; TCCS 31: 2020 – Highway – Specification for Survey 22TCN 356:2006 – Modified polymer hot asphalt mix – Construction and quality control	2021 - 2022
2	TCVN 4054:2005 - Highway - Specifications for design TCXD 104:2007 – Urban roads – Specification for design; QCVN 7 – 04: 2016 – National technical regulation for transport infrastructure. TCVN 10380:2014 – Rural roads – Specification for design TCVN 9845: 2013 Calculation of flood flow characteristics corresponds QCVN 02: 2021/BXD – Natural Physical and Climate Data for Construction	2022 - 2023
3	TCVN 9436 : 2012 - Highway embankments and cuttings – Construction and quality control TCVN 8819: 2011 – Hot Asphalt Mix – Construction and quality control TCCS 07: 2013 – Road routine maintenance specification Norm of Road Routine Maintenance under No.3479: 2014 Decision	2021 - 2022
4	Recycling and waste materials Low emission construction material and technology	2022 - 2025
5	Develop Technical Guideline of Environment-based and Climate Change Adaptation Road Design	2021 - 2022

Details of the updated stipulations of the proposed standard updates are provided in the TA final report (Annex C – Table C.1)

ANNEX A

A listing of Relevant Domestic, Regional and International Guidance on Climate Change Resilience

World Bank Support Team
Final Report Nov 2021

WORLD BANK GROUP

Ref Paper	Author	Yr	Title
1045	ADB	2009	The Economics of Climate Change in Southeast Asia: A Regional Review
1055	ADB	2011	Guidelines for Climate Proofing Investment in the Transport Sector: Road Infrastructure Projects.
1061	ADB	2018	Adjusting Hydrological Inputs to Road designs for Climate Change Risk Guidelines to Apply Extreme Value Analysis.
1082	ADB	2011	Lao PDR Transport Sector Assessment, Strategy, and Road Map
1090	ADB	2014	Climate Risk Management in ADB Projects
1092	ADB	2014	Climate Proofing ADB Investment in the Transport Sector Initial Experience.
1096	ADB	2014	Mainstreaming Adaptation into Development Plans in Vietnam. Case Study 1.5
1111	ADB	2015	Economic analysis of climate proofing investment projects.
1153	ADB	2020	Manual on Climate Change Adjustments for Detailed Engineering Design of Roads Using Examples from Viet Nam.
1154	ADB	2020	Climate Change Adjustments for Detailed Engineering Design of Roads—Experience from Viet Nam.
1167	ADB	2017	Adjusting hydrological inputs to road design for climate change risk. Guidelines to apply extreme value analysis. ADB PPTA 8957. Draft
1042	ADB, Veron	2014	Toward a Sustainability Appraisal Framework for Transport.
1007	ADB, ICEM	2007	Promoting Climate Resilient Rural Infrastructure in Northern. Vietnam, Technical Report 4: Vulnerability Assessment and Adaptation Response Workshop. Prepared for Ministry of Agriculture and Rural Development and Asian Development Bank. Hanoi
1012	ADB, ICEM	2014	Promoting Climate Resilient Rural Infrastructure in Northern Vietnam. PPT. Approach and Methodology.
1013	ADB, ICEM	2014	Promoting Climate Resilient Rural Infrastructure in Northern Vietnam. PPT. Climate change vulnerability assessment.
1014	ADB, ICEM	2014	Promoting Climate Resilient Rural Infrastructure in Northern Vietnam. Climate and Hydrology: The Son La Sites.
1113	ADB, ICEM	2017	Promoting Climate Resilient Rural Infrastructure in Northern Vietnam, Final Report. Prepared for Ministry of Agriculture and Rural Development and Asian Development Bank. Hanoi
1019	ADB, MPWT	2017	First Draft Road Design Manual. Government of Laos. Ministry of Public Works and Transport, Department of Roads.
1062	ADB-ICEM	2017	TA8102-VIE: Promoting Climate Resilient Rural Infrastructure in Northern Viet Nam TR-18 Slope Protection Designs and Specifications.
1063	ADB-ICEM	2017	Promoting Climate Resilient Rural Infrastructure in Northern Vietnam, Technical Report 17: Bioengineering – Field Guidelines for Slope Protection.
1109	ADB-ICEM	2017	TA8102-VIE: Promoting Climate Resilient Rural Infrastructure in Northern Viet Nam. Effectiveness Audit Report. TR14
1110	ADB-ICEM	2017	TA8102-VIE: Promoting Climate Resilient Rural Infrastructure in Northern Viet Nam. Construction Completion Report TR16.
1024	ADPC	2014	Comprehensive Multi Hazard Risk Assessment in Lao PDR Training Handbook for National and Provincial Government officials.

Ref Paper	Author	Yr	Title
1010	Albert Salamanca, Ha Nguyen	2016	Climate change adaptation readiness in the ASEAN countries. Supplemental Tables.
1029	Anon	2014	Status Climate Change Strategy and Implementation, Lao PDR. PPT at 2nd Mekong Climate Change forum, 2014.
1030	Anon	2015	Intended Nationally Determined Contribution (INDC) Development in Laos. 24th Asia-Pacific Seminar on Climate Change on INDCs,29-30 June 2015, Bangkok, Thailand.
1081	APDC	2010	National Risk Profile of Lao PDR
1011	Arief Anshory Yusuf & Herminia Francisco	2009	Climate Change Vulnerability Mapping for Southeast Asia. Economy and Environment Program for Southeast Asia (EEPSEA)
1028	Asian Disaster Preparedness Center (ADPC	2016	Policy Guideline: Mainstreaming Disaster and Climate Risks into the Public Investment Project Process in Lao PDR. WB Lao DRM Project I.
1018	Asian Disaster Preparedness Center (ADPC)	2016	Mainstreaming Disaster and Climate Risks into the Public Investment Project Process in Lao PDR. WB Lao DRM Project Procedures and Guidelines for Risk Assessment of Transport Sector.
1027	Asian Disaster Preparedness Center (ADPC)	2016	Policy Guideline: Mainstreaming Disaster and Climate Risks in the 8th National Socio-Economic Development Plan (NSEDP) of Lao PDR, 2016-2020. WB Lao DRM Project I.
1033	Asian Disaster Preparedness Center (ADPC).	2016	Procedures and Guidelines for Risk Assessment of Transport Sector.
1193	Becker, A.H.	2013	A note on climate change adaptation for seaports: a challenge for global ports, a challenge for global society. Climatic Change 120, 683–695 (2013). https://doi.org/10.1007/s10584-013-0843-z
1193	Bipartisan Policy Center,	2009	Transportation Adaptation to Global Climate Change. National Transportation Policy Project, Washington, D.C.
1083	CFE-DM	2017	Lao PDR Disaster Management Reference Handbook.
1199	Chinowsky, P., Schweikert, A., Strzepek, N.,1 and Strzepek, K.	2015	Road Infrastructure and Climate Change in Vietnam. Sustainability 2015, 7, 5452-5470; doi:10.3390/su7055452
1020	CIPPEC	2012	How to communicate research for policy influence. Toolkit No.2. Policy Briefs.
1198	Cook J R	2021	
1125	Cook J R.	2012	Climate resilient rural roads. Technical Paper No. 1. The Vietnam rural road surfacing research programme 2002-2012 Technical summary. Consultant Report to World Bank, Hanoi.
CR28	Cook J. R. & Petts R.C.	2005	Rural road gravel assessment programme. SEACAP 4, Module 4, Final Report. DfID Report for MoT, Vietnam.
CR32	Cook J.R. & Bounta Meksavanh	2009	Performance monitoring of low volume rural roads in Northwest Lao PDR. SEACAP 17.02 DfID for MPWT.
1114	CSIRO (Australia)	2014	High-resolution climate projections for Vietnam. www.csiro.au.
1040	DDMCC-MONRE, Laos	2015	24th Asia-Pacific Seminar on Climate Change on INDCs. Intended Nationally Determined Contribution (INDC) Development in Laos.
1054	DDMCC-MONRE, Laos	2015	Intended Nationally Determined Contribution (INDC) Development in Laos.

Ref Paper	Author	Yr	Title
1193	de Bruin, K. et al	2009	Adapting to climate change in The Netherlands: an inventory of climate adaptation options and ranking of alternatives. Climatic Change (2009) 95:23–45 DOI 10.1007/s10584-009-9576-4
1174	De Nijs, A. & Shannon, K.	2011	Controlled Landscapes and (re) Designed Nature. Climate change knowledge and practices in the Mekong Delta, the case of Can Tho. N-AERUS XI
1038	De Souza et al	2015	Vulnerability to Climate Change in Three Hot spots in Africa and Asia.
1129	DFID	2012	Climate change adaptation, mitigation and low carbon development. Infrastructure:Rapid Evidence Reviews. Evidence on Demand for DFID
1093	Do Minh Duc,Yasuhara K, Nguyen Manh Hieu & Nguyen Chau Lan	2017	Climate Change Impacts in a Large-Scale Erosion Coast of Hai Hau District, Vietnam.
1097	DRVN, MoT Vietnam	2018	Consulting services for developing guidance on climate resilience in local road and bridge network - LRAMP. Document 1 Climate change to roads and assessing vulnerability level of roads due to climate change.
1098	DRVN, Mot Vietnam	2018	Consulting services for developing guidance on climate resilience in local road and bridge network - LRAMP Document. Guidelines on hydrological analysis and calculation for local bridge and water drainage construction designs adapting to climate change.
1099	DRVN, MoT Vietnam	2018	Consulting services for developing guidance on climate resilience in local road and bridge network - LRAMP. Document III. Guideline for application of technical solutions in design and construction of local roads adapting climate change .
1101	DRVN, MoT Vietnam	2018	Consulting services for developing guidance on climate resilience in local road and bridge network - LRAMP. Document 5 Long-term development of local transports: Priorities in management, planning and assessment of climate change adaptation measurements.
1100	DRVN, MoT Vietnam.	2018	Consulting services for developing guidance on climate resilience in local road and bridge network - LRAMP. Document 4 Key Considerations in Maintenance of Local Roads adapting to Climate Change.
1002	ERA-NET ROAD	2010	Risk Management for Roads in a Changing Climate: A Guidebook to the RIMAROCC Method. https://trimis.ec.europa.eu/sites/default/files/project/documents/01_Rimarocc%20Guidebook.pdf
1077	ERA-NET Road	2009	State of the art of materials' sensitivity to moisture content change.
1078	ERA-NET Road	2009	State of the art of likely effect of climate on current roads.
1079	ERA-NET Road	2010	Pavement Performance & Remediation Requirements following Climate Change. P2R2C2.
1053	Ford	2015	The Status of Climate Change Adaptation in Africa and Asia.
1031	GCCA	2012	GCCA, 2012. The Lao PDR Global Climate Change Alliance Programme. http://www.gcca.eu.
1107	Geddes R.	2017	Economic Growth through Effective Rural Road Asset Management.
1022	GFDRR	2011	Climate Risk and Adaptation Country Profile.

Ref Paper	Author	Yr	Title
1143	Giang P Q	2021	Prediction of the Variability of Changes in the Intensity and Frequency of Climate Change Reinforced Multi-Day Extreme Precipitation in the North-Central Vietnam Using General Circulation Models and Generalized Extreme Value Distribution Method.
1009	GITECH	2014	Guideline in Climate Adaptation for RIP Rural Roads. KfW PPS for RIP Phase IV, MPWT, DoR
1080	GIZ	2015	Impact Evaluation Guidebook for Climate Change Adaptation Projects.
1131	GIZ	2018	Nationwide climate vulnerability assessment in Bangladesh. Ministry of Environment, Forest and Climate Change
1015	Global Climate Change Alliance (GCCA)	2012	The Lao PDR Global Climate Change Alliance Programme.
1048	GoL	2011	The Seventh Five-year National Socio-Economic Development Plan (2011-2015)
1132	Gov. of Vietnam	2020	Updated Nationally Determined Contribution (NDC- 2020)
1133	Gov. of Vietnam	2015	Intended Nationally Determined Contribution (NDC- 2015)
1127	Howell J.	2008	Study of road embankment erosion. SEACAP 19 Technical Paper 6. DfID paper for MRD, MPWT, Cambodia.
1025	ICEM	2011	Climate Change and Adaptation and Mitigation Methodology or CAM.
1155	ICEM-ADB	2012	Mekong Delta Central Connectivity Project: Rapid Climate Change Threat and Vulnerability Assessment. Final Report.
1041	IFC-WB	2016	How to Make Infrastructure Climate Resilient
1126	ILO & Don Bosco	2014	Manual, Labour-based Technology for Rural Road Maintenance Timor-Leste, ISBN: 978-92-2-129457-3
1087	IMHEN	2011	Technical Guidance for the Assessment of Climate Change Impacts and the Identification of Adaptation Measures. Vietnam Institute of Meteorology, Hydrology and Environment .
1104	IMHEN-UNDP	2015	Viet Nam Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation
CR31	Intech-TRL	2006	SEACAP 1 Final Report (3 vols). DfID Report for MoT, Vietnam.
1047	IPCC	2014	IPCC Climate Change 2014 Synthesis Report .
1191	IPCC	2013	Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Summary for Policy Makers
1194	IPCC	2007	Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. e, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds. Summary for Policymakers
1065	JICA	2013	Draft Slope Maintenance Manual.
1076	JICA	2014	The Project on Riverbank Protection Works Phase II.
1118	JICA	2018	Project for capacity enhancement in road maintenance. Phase II. Final Report. For DRVN, Mot, Vietnam.
1119	JICA	2014	Support for establishment of national technical regulation/ standards (QCVN/TCVN). Final Report. For DRVN/MoT, Vietnam.

Ref Paper	Author	Yr	Title
1008	JICA, ADPC	2014	Mainstreaming Disaster and Climate Risk Management into Investment Decisions. Report on Training for National and Provincial Government Officials on Comprehensive Multi-Hazard Risk Assessment in Lao PDR
1122	Jones T.E. & Promprasith Y.	1991	Maintenance of unpaved roads in wet climates. 5th Int Conf. On Low Volume Roads, TRR 1291.
1189	Karl, T.R., Melillo, J.M. and Peterson, T.C.,	2009	Global Climate Change Impacts in the United States. United States Global Change Research Program, Cambridge University Press, New York.
1051	Lea Berrang-Ford	2015	Systematic Review Approaches for Climate Change Adaptation Research.
1190	Matthews, T.	2011	Climate Change Adaptation in Urban Systems: Strategies for Planning Regimes. Urban Research Program. Research Paper 32.
1060	McGray H, Dinshaw, A and Dixit A World Resources Institute.	2016	Toward Decision-Relevant Information Systems for Adaptation to Climate Change in South Asia.
1057	McPherson & Bennett	2005	Success Factors for Road Management Systems.
1197	Meyer M. D.	2008	Design Standards for U.S. Transportation Infrastructure The Implications of Climate Change. Transportation Research Board, National Research Council.
1032	Ministry of Planning and Investment (MPI).	2016	8th Five-Year National Socio-economic Development Plan (NSEDP 2016–2020).
1023	MoNRE (GoL)	2013	Technology Needs Assessment Project. Climate Change Adaptation.
1075	MonRE GoL	2015	Community-Based Disaster Risk Reduction (CBDRR) Manual in Lao PDR.
1088	MONRE GoV	2016	Climate Change and Sea Level Rise Scenarios for Viet Nam. Ministry of Natural Resources and Environment. Vietnam. http://imh.ac.vn/files/doc/KichbanBDKH/CCS_SPM_2016.pdf.
1091	MONRE Vietnam	2009	Climate Change and Sea Level Rise Scenarios for Viet Nam.
1039	MoNRE, Lao PDR	2014	Status Climate Change Strategy and Implementation Lao PDR.
1106	MONRE, Vietnam	2016	Climate Change Impacts and Adaptation Efforts in Vietnam.
1036	MPWT	2017	Aligning Public Works Transport Development Sector Plan.
1037	MPWT	2017	Sub Sector Working Group on Infrastructure Development and Road Maintenance.
1185	Nasra, A. et al	2020	Bridges in a changing climate: a study of the potential impacts of climate change on bridges and their possible adaptations. Structure and Infrastructure Engineering. Vol 16, No. 4, 738–749 https://doi.org/10.1080/15732479.2019.1670215
1052	NDF-WB	2016	Climate Resilient Roads, Cambodia.
1196	Neumann, J., et al	2015	Climate change risks to US infrastructure: impacts on roads, bridges, coastal development, and urban drainage. Climatic Change 131:97–109 DOI 10.1007/s10584-013-1037-4
1094	Nguyena V N, Ginigea K & Greenwood D	2017	Challenges in integrating disaster risk reduction into the built environment – The Vietnam context.

Ref Paper	Author	Yr	Title
1021	OPM	2014	Strategic Research into National and Local Capacity Building for DRM. Inception Report.
CR33	OTB-LTEC	2009	Performance monitoring of NEC-ADB Package 1 trial and gravel roads. SEACAP 17.02 Final Report. DfID for MPWT Lao PDR.
1056	Quintero Juan D.	2010	A Guide to Good Practices for Environmentally Friendly Roads.
1117	Rai N, Kaur N, Greene S, Wang B, Steele P	2015	A guide to national Governance of climate finance. International Institute for Environment and Development (IIED) and Department for International Development (DFID). Evidence on Demand. Http://dx.doi.org/10.12774/eod_tg.march2015.rainetal
1006	ReCAP	2017	Climate Adaptation: Risk Management and Resilience Optimisation for Vulnerable Road Access in Africa: Climate Adaptation Handbook
1112	ReCAP	2017	Climate Adaptation: Risk Management and Resilience Optimisation for Vulnerable Road Access in Africa; Engineering Adaptation Options Report
1177	ReCAP	2019	Climate Adaptation: Risk Management and Resilience Optimisation for Vulnerable Road Access in Africa: Change Management Guideline. CSIR for DfID-ReCAP
1178	ReCAP	2019	Climate Adaptation: Risk Management and Resilience Optimisation for Vulnerable Road Access in Africa: Climate Threat and Vulnerability Assessment Guideline. CSIR for DfID-ReCAP
1179	ReCAP	2019	Climate Adaptation: Risk Management and Resilience Optimisation for Vulnerable Road Access in Africa: Visual Assessment Manual. CSIR for DfID-ReCAP
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CR36	Rolt J.	2008	Bamboo reinforced concrete pavements. SEACAP 19 Technical paper 1. DfID for MRD, MPWT Cambodia.
CR37	Rolt J.	2007	Behaviour of engineered natural surface roads. SEACAP 19 Technical Paper 2.1. DfID for MRD, MPWT, Cambodia.
CR38	Rolt J. Cook J.R. & Kackada H.	2008	Behaviour of engineered natural surfaced roads; experimental evidence in Cambodia. SEACAP 19 Technical Paper 2.2. DfID report for MRD, MPWT, Cambodia.
1115	Roux, M. et al	2019	Embedment of climatic effects in the road asset management process. 26th World Road Congress, Abu Dhabi, 2019.
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1049	SEA Change CoP	2014	Selecting indicators for climate change adaptation programming.
1034	Shuaib Lwasa	2015	A systematic review of research on climate change adaptation policy and practice in Africa and South Asia deltas. Regional Environmental Change Volume 15, Issue 5,
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1016	Syamphone SENGCHANDALA	2010	Global Climate Change Alliance (GCCA). PPT. 8thWorkshop on GHG Inventories in Asia (WGIA8).
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1123	Thornthwaite C. W.	1948	An approach towards a rational classification of climate. Geographical Review, Vol 58, 55-94.

Ref Paper	Author	Yr	Title
CR34	TRL-LTEC	2008	Low volume rural roads standards and specifications; Part II Pavement options and technical specifications. SEACAP 3, DfID for MPWT Lao PDR.
CR35	TRL-LTEC	2008	Low volume rural roads standards and specifications; Part I Classification and geometric standards. SEACAP 3, DfID for MPWT Lao PDR.
1120	TRL-OTB-LTEC	2009	Low volume rural road environmentally optimised design manual. For DfID and MPWT Lao PDR.
1116	Tull, K.	2019	Development, Climate and Environment: An Annotated Bibliography. K4D Helpdesk Report 644. Brighton, UK: Institute of Development Studies.
1050	UN Framework Convention on CC	2011	Assessing Climate Change Impacts and Vulnerability Making Informed Adaptation Decisions
1187	UNCTAD	2013	Ad Hoc Expert Meeting on Climate Change Impacts and Adaptation: A Challenge for Global Ports. Notes.
1085	UNISDR	2009	UNISDR Terminology on Disaster Risk.
1046	United Nations Framework Convention on Climate Change	2009	Impacts, Vulnerabilities, and Adaptation in Developing Countries.
1084	UNPD	2012	Technical Guidance for Intergrating Climate Change into Development Plans (Vietnam).
1044	UNU WIDER Chinowsky	2012	Road Infrastructure and Climate Change in Vietnam
1043	UNU WIDER Neumann	2012	Risks of Coastal Storm Surge and the Effect of Sea Level Rise in the Red River Delta, Vietnam
1186	US FHWA	2013	Planning for Systems Management & Operations as part of Climate Change Adaptation. FHWA. FHWA-HOP-13-030
1026	USAID	2015	USAID Mekong Adaptation and Resilience to Climate Change (USAID Mekong ARCC), Final Report.
1103	Van C T, Tri D Q, , Son N T , Thao T T, and Hoa D T H.	2019	Determining the vulnerability index in the context of high floods in An Giang Province.
1066	WB-ADPC	2014	Landslide Inventory Framework for Critical National and Provincial Roads in Lao PDR.
1067	WB-ADPC	2014	National and Provincial Risk Assessment off Lao PDR Vol. I : Hazard & Element at Risk Risk.
1068	WB-ADPC	2014	National and Provincial Risk Assessment off Lao PDR Vol.2 : Exposure, Vulnerability, Risk Assessment.
1069	WB-ADPC	2014	Strategic Guideline .Mainstreaming Disaster and Climate Risks into the Road Sector in Lao PDR.
1070	WB-ADPC	2014	Procedure & Guidelines for Risk Assessment of Transport Sector
1071	WB-ADPC	2014	Technical Guideline Resilient Road Infrastructure in Lao PDR
1072	WB-ADPC	2014	Lesson Learn From Good Practices Resilient Infrastructure and its Relevance to Lao PDR.
1074	WB-ADPC	2014	Mainstreaming Disaster and Climate Risk Management into Investment Decisions Road Slope Risk Assessment in Lao PDR.
1073	WB-MPWT	2017	SEA DRM Project – Lao PDR. Ethnic Groups Engagement Framework

Ref Paper	Author	Yr	Title
1128	Weinart H.H.	1974	A climatic index of weathering and its application in road construction. Geotechnique 24, 475-488.
1089	Wilby R.	2019	Climate Change Adjustments for Detailed Engineering Design with Worked Examples from Viet Nam
1003	World Bank	2017	Scope of the road geohazard management handbook.
1017	World Bank	2017	Integrating Climate Change into Road Asset Management.
1058	World Bank	2013	Turn Down the Heat: Climate Extremes, Regional Impacts, and the Case for Resilience.
1064	World Bank	2018	The Second South Asia Regional South-To-South Learning Workshop on Building Resilience to Landslide and Geohazard Riskin Transport Sector.
1102	World Bank	2019	Addressing Climate Change in Transport. Volume 2: Pathway to Resilient Transport
1105	World Bank	2015	Making Transport Climate Resilient.
1108	World Bank	2011	Climate-Resilient Development in Vietnam: Strategic Directions for the World Bank.
1121	World Bank	2005	Notes on the economic evaluation of transport projects. Low volume roads. WB Transport note TRN 21, Washington.
1152	World Bank	2018	Metadata of the Climate Change Knowledge Portal.
1173	World Bank	2010	Natural Disasters and Household Welfare Evidence from Vietnam. Policy Research Working Paper 5491
1175	World Bank	2010	Economics of Adaptation to Climate Change. Synthesis Report.
1176	World Bank	2010	Vietnam: Economics of Adaptation to Climate Change.
1059	World Bank, Ebinger, Vandyke	2015	Moving Toward Climate-Resilient Transport: The World Bank's Experience from Building Adaptation into Programs
1005	World Bank; Arup	2017	Incorporating Climate Risk into Performance-Based Contracting
1004	World Bank; IMC Worldwide	2014	Disaster Risk Management in the Transport Sector. A Practical Guidance Note
1086	World Bank-IMC.	2015	Disaster Risk Management in the Transport Sector. A Review of Concepts and International Case Studies. World Bank report.98202. http://documents.worldbank.org/curated/en/524081468188378328/pdf/98202-WP-P126896-Box391506B-PUBLIC-DRM-Final.pdf
1001	World Road Association – PIARC	2015	International Climate Change Adaptation Framework for Road Infrastructure, WRA/PIARC
1005	WREA	2015	Lao PDR National Adaptation Programme of Action (NAPA).

ANNEX B

Summaries of Key Domestic, Regional and International Guidance and Experience with Integration of CCR in Transport Planning

World Bank Support Team
Final Report Nov 2021

WORLD BANK GROUP

B1: Vietnam Specific Documents

Database Ref. No.	Document	Summary	Key Lessons for NDC
1007	ICEM. 2014. Promoting Climate Resilient Rural Infrastructure in Northern Vietnam, Final Report.	Overall report on low-cost climate-proofing measures suitable for rural infrastructure in northern Viet Nam; demonstration of climate resilient techniques in the provinces of Bac Kan and Son La on two rural roads, one irrigation scheme, and one river embankment; associated training materials; recommendations for the integration into training curricula, standard design procedures, and contract specifications; and identification of climate change risks and vulnerabilities.	Provides links to sperate documents on standard design procedures, costs and specifications for bioengineering
1043	Neumann. 2012. Risks of Coastal Storm Surge and the Effect of Sea Level Rise in the Red River Delta, Vietnam. UNU-WIDER.	The impact of sea level rise and storm surge on the Red River delta region of Vietnam an area already known to be highly vulnerable to coastal risks. Analysis of permanently inundated lands and temporary flood zones shown and vulnerability methodology demonstrated for disaster planning and vulnerability assessment purposes.	This document demonstrates a vulnerability methodology for disaster planning and vulnerability assessment purposes.
1044	Chinowsky. 2012. Road Infrastructure and Climate Change in Vietnam. UNU-WIDER.	Focus on the physical asset of road infrastructure in Vietnam by evaluating the potential impact of changes from climate including sea level rise, precipitation, temperature and flooding. Mean additional cost of maintaining the same road network through 2050 amount to US$10.5 billion.	This document recognises climate change adaptation as an important component of planning and policy in the current and near future.
1061	ADB. 2018. Adjusting Hydrological Inputs to Road designs for Climate Change Risk Guidelines to Apply Extreme Value Analysis.	Roads and bridges are identified as vulnerable infrastructure elements due to increased flood risk in Vietnam. The assessment recommends that detailed engineering designs incorporate increased flooding risk due to climate change. The report describes an approach for including climate change in the detailed design of roads and associated structures. The guidelines serve two purposes. First, they provide background understanding on the rationale for re-assessing design flood levels to consider climate change impacts based on climate modelling projections. Second, they described steps to guide practitioners in adjusting design flood levels.	Provides guidance on working effectively within existing standards and guidelines.

Database Ref. No.	Document	Summary	Key Lessons for NDC
1084	UNPD, 2012. Technical Guidance for Integrating Climate Change into Development Plans (Vietnam). Institute of Meteorology, Hydrology and Environment	The Government of Vietnam programs have identified that one of the important tasks is to integrate climate change into socio-economic development strategies, planning processes and plans to implement the activities of climate change response effectively and align the objective of climate change response and sustainable socio-economic development.	This document aims to provide policy-makers from the central to local levels with general information on climate policy integration, the activities implemented before mainstreaming, the mainstreaming process as well as the tools that may be used to support the process of mainstreaming climate change into socio-economic development plans.
1062	TA8102-VIE: Promoting Climate Resilient Rural Infrastructure in Northern Viet Nam TR-18 Slope Protection Designs and Specifications. ADB-ICEM.	Provides the detailed technical designs of selected bioengineering and associated engineering options used to protect and increase the resilience of roadside slopes and riverbanks against surface erosion and shallow failure. Has a long term purpose of establishing a critical mass of trained engineers and technicians able to use bioengineering as a low-cost, climate resilient tool.	The document includes the drawings cost norms and specifications for 16 techniques that were physically demonstrated at five sites in four locations in three provinces of northern Vietnam.
1063	Promoting Climate Resilient Rural Infrastructure in Northern Vietnam, Technical Report 17: Bioengineering – Field Guidelines for Slope Protection. ADB-ICEM.	Provides guidance on the selection of appropriate bioengineering and associated engineering options for the surface protection of roadside slopes and riverbanks, and to increase their resilience to extreme climatic events. Although the guidance is aimed primarily at rural infrastructure, its principles may be adapted for use in other slope protection environments. Generally appropriate for immediate protection of both cut and fill slopes and riverbanks against surface erosion and shallow mass movement. In the longer term, they increase the resilience of the sites to withstand extreme climatic events.	Bioengineering and low cost engineering techniques demonstrated by this project are described in detail and illustrated in this document.
1087	IMHEN 2011. Vietnam Institute of Meteorology, Hydrology and Environment Technical Guidance for the Assessment of Climate Change Impacts and the Identification of Adaptation Measures..	This document develops a detailed guidance on the method of assessment of climate change impacts and identification of specific adaptation measures. It aims to assist the state, non-governmental organizations and the private sector to: • Implement the climate impact assessment at city/provincial level; • Prioritize climate change impacts for consideration; • Identify adaptation measures; • Select appropriate adaptation measures.	Contains tools for assessing climate change in various sectors including transport. Contains a section on the position of impact assessment in the planning process for climate change response.

Database Ref. No.	Document	Summary	Key Lessons for NDC
1088	MONRE GoV, 2016. Climate Change and Sea Level Rise Scenarios for Viet Nam. Ministry of Natural Resources and Environment. Vietnam. http://imh.ac.vn/files/doc/KichbanBDKH/CCS_SPM_2016.pdf	Provides scenarios of climate change and sea level rise for Viet Nam as updated in 2016 following the roadmap defined in the National Strategy on Climate Change. The document provides the latest information on the trends of climate change and sea level rise in recent years, as well as climate change and sea level rise scenarios for Viet Nam in the 21st century. Recommendations include when applying climate change and sea level rise scenarios for impact assessments, it is necessary to consider and analyse carefully all the possible occurrences of a future climate.	The document makes recommendations on procedures in determining climate change scenarios as well as the most relevant changes in the planning process.
1089	Wilby R. 2019. Climate Change Adjustments for Detailed Engineering Design with Worked Examples from Viet Nam. An ADB Knowledge Product.	This Knowledge Product (KP) explains the rationale and procedures for incorporating allowances for climate change in detailed engineering design (DED). Attention is focused on credible adjustments to extreme rainfall, mean and high-end sea level rise. The DED should reflect the possibility of climate-driven changes in multi-hazards at a site. The procedures are demonstrated with worked examples drawn from the Viet Nam road transport sector and peer reviewed research literature. An accompanying Step-by-Step Manual shows how each calculation is performed. These principles and practices are intended to be transferrable to other sectors, regions and stages of asset life-cycle (from project concept to decommissioning).	This document indicates how procedures can be undertaken within the existing Vietnam regulatory framework. Links are included for specific Policy and Practice of Adaptation in the Coastal Zone
1095	Takagi H, Esteban M & Thao D. 2014. Introduction: Coastal Disasters and Climate Change in Vietnam.	Introduction to the book "Coastal Disasters and Climate Change in Vietnam: Engineering and Planning Perspectives" which attempts to describe the present day state of Vietnamese coasts. It also provides the latest information regarding various engineering and social challenges, along with state-of-the art academic research findings regarding how to adapt against the risks associated with coastal disasters and future climate change in Vietnam. It also looks at crucial management and adaptation efforts.	Provide references to the main book – including management actions required for seal level rise adaptations. Provides specific examples.
1096	ADB, 2014. Mainstreaming Adaptation into Development Plans in Vietnam. Case Study 1.5	Challenges are pressuring Vietnam to step up its policy-making efforts and measures to enhance public awareness and capacity to address climate change impacts, while also promoting economic development. Vietnam has seen high economic growth rate in the past decades.	This document summarises with diagrams the current frameworks for mainstreaming climate adaptation with responsibilities split between different ministries and departments and frequently delegated down to province and district levels. Recommendations are made for institutional and management improvement.

Database Ref. No.	Document	Summary	Key Lessons for NDC
1097	MoT. 2018. Guidance on Climate Resilience in Local Road and Bridge Network. 1. Climate change to roads and assessing vulnerability level of roads due to climate change.	This document provides background to issues of climate resilience for the Vietnam road network. Climate change is summarised for regions of Vietnam and the various impacts are summarised. The document introduces of the concept of road vulnerability, sensitivity and adaptability. Three methods of assessing vulnerability to climate change, from simple to complex, are developed as a guide to use in local road projects.	Appendices include detail on (A) Climate Change Trends in Climate Regions (B) Quantifying component indexes of Sensitivity (D) Quantifying component indexes of Adaptability. Appendix D. Proposes some indicators to assess the vulnerability level of local roads. This draft requiring significant editing
1098	MoT. 2018. Guidance on Climate Resilience in Local Road and Bridge Network. Document 2: Guidelines on hydrological analysis and calculation for local bridge and water drainage construction designs adapting to climate change.	Document No. 2 provides guidance on hydrological analysis and calculation for the design of small bridges and drainage works to adapt to climate change. It includes (1) Climate change factors in hydrological analysis and hydraulic calculation of drainage works in the areas of the LRAMP. (2) Guidance on collecting and surveying input data and analyzing for small bridges and drainage works to adapt to climate change in the LRAMP. (3) Guidance on hydrology, hydraulic calculation of culverts and drainage works on roads to adapt to climate change. (3) Guidance on hydrological analysis and calculation of bridges to adapt to climate change..	This document works within existing regulatory framework but does not really deal effectively with climate change. Provides useful links to exiting standards etc but This draft requiring significant editing
1099	MoT. 2018. Guidance on Climate Resilience in Local Road and Bridge Network. Document 3. Guideline for application of technical solutions in design and construction of local roads adapting climate change	Document 3 focuses on providing adaptation solutions to climate change in the design and construction of local roads. Specifically including the following: (1) Guidance for conducting survey for local road design to adapt to climate change. (2) Technical solutions in designing traffic to adapt to climate change. (3) Solutions to the construction process to adapt to climate change. (4). Guidance on the application of bioengineering in construction slope protection.	Provides guidance on adaptation options but this draft requires significant editing.
1100	MoT. 2018. Guidance on Climate Resilience in Local Road and Bridge Network. Document 4: Key considerations in maintenance of local road adapting to climate change	The Guideline on maintenance of local roads in the climate change context aims to provide necessary technical guidance to facilitate road managers and technical staff (at district and commune levels) and local people as well as other organizations and individuals involving in local road maintenance to implement their job effectively. This guideline needs to be considered and applied together with the technical instructions mentioned above. The guideline includes the following: (1) The general concepts of road maintenance in the context of climate change adaptation. (2) Preparation of maintenance plan for local roads considering climate change.(3) Organization local roads maintenance, including local communities. (4) Technical maintenance instructions to improve the adaptability of local roads to climate change.	Does not really deal with climate change and hence this draft requires significant editing.

Database Ref. No.	Document	Summary	Key Lessons for NDC
1101	MoT. 2018. Guidance on Climate Resilience in Local Road and Bridge Network. Document 5. Long-term development of local networks: Priorities in management, planning and assessment of climate change adaptation measurements.	Document No. 5 focuses on the long-term development of local roads with priorities in planning, management and evaluation of climate change adaptation measures, including the following: (1) Criteria for dealing with roads and structures on roads damaged by climate change; (2) Guidelines on prioritizing climate impacts and enhancing climate adaptation;(3) Guidelines on prioritizing climate impacts and enhancing climate adaptation..	Deals to some extent with planning and prioritisation but contains misleading suggestions and this draft requires significant editing
1102	World Bank 2019. Addressing Climate Change in Transport. Volume 2: Pathway to Resilient Transport. World Bank Vietnam Transport Knowledge Series. (Jung Eun Oh, Alegre X O, Pant R, Koks E E, Russell T, Schoenmakers R, & Hall J W.)	A vision and strategy for climate-smart transport, in order to minimize the carbon footprint of the sector while ensuring its resilience against future risks. Presented in two volumes: V1—Pathway to Low Carbon Transport and V 2—Pathway to Resilient Transport. This 2nd volume provides a methodological framework to analyze network criticality and vulnerability, and to prioritize investments to enhance resilience. Presents the results from the Transport Multi-Hazard Risk Analysis at national and provincial scales. The national analysis covers key national-scale roads, railways, civil aviation, inland waterways, and maritime systems in Vietnam. At the national scale using 3 provinces Lao Cai, Binh Dinh, and Thanh Hoa, to understand the economic impacts of disruptions to multimodal freight transportation due to infrastructure failures.	Presents the results from the Transport Multi-Hazard Risk Analysis at national and provincial scales in order to understand. the economic impacts of disruptions to multimodal freight transportation due to infrastructure failures.
1103	Van C T, Tri D Q, , Son N T , Thao T T, and Hoa D T H. 2019. Determining the vulnerability index in the context of high floods in An Giang Province"	The vulnerability, flood hazards, and exposure are three indicators to calculating and assessing flood risk in the Mekong Delta river. The vulnerability index is based on three criteria, including sensitivity and adaptive capacity related to the economic, social, and environmental aspects and benefits that floods bring to the Mekong Delta river.. This paper uses the vulnerability index method which is the sum of the components including the sensitivity, resilience and benefits of floods to calculate and assess the flood vulnerability of 155 communes in 11 districts of An Giang province.	Flood vulnerability index (FVI) is a factor to estimate hazards and vulnerability including adaptive capacity, exposure, and sensitivity, which might be applied for master planning.
1104	IMHEN-UNDP- 2015. Viet Nam Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation.	The SREX Viet Nam assesses extreme events and their impact on the natural environment, social economic development and sustainable development of Viet Nam; the future changes in extreme climate events due to climate change; interactions between climatic, environmental and human factors; and promote adaptation to climate change and management of risks of disaster and extreme events in Viet Nam.	Disaster risk management and adaptation to climate change focus on reducing exposure and vulnerability and increasing resilience to the potential adverse impacts of climate extremes, even though risks cannot fully be eliminated

Database Ref. No.	Document	Summary	Key Lessons for NDC
1108	World Bank. 2011 Climate-Resilient Development in Vietnam: Strategic Directions for the World Bank.	This report presents some strategic thinking on how the World Bank can prioritize our assistance on climate change to Vietnam. The report outlines the current (2011) understanding of what climate change actually means for Vietnam, relying heavily on the government's own scenarios. Short texts on each of a few key adaptation and mitigation sectors outline challenges, and opportunities, and present Bank activities. The report lays out some key priorities for Bank activities and funding.	The report includes a Moving Forward section which addresses the question of "How?", with a focus on the kinds of assistance the Bank can offer, with particular emphasis on emerging funding opportunities.
1114	CSIRO (Australia), 2014. High-resolution climate projections for Vietnam. www.csiro.2011.au.	Enhancing Vietnam's capacity to develop regional scale climate projections, enabling more robust national and provincial climate change action plans to underpin adaptation planning and to prioritise investment. This document provides links to the Climate Futures Tool (http://climatetool.vnclimate.vn/) which allows the end user to view the spread of possible projections for the seven sub-regions of Vietnam. In addition, the Tool guides the end user in choosing possible projections that may be used to assess the impact of climate change for different applications.	Three stages in pathway to future climate change adaptation planning in Vietnam consisting of three linked phases Phase 1 focused on 'capacity building'; Phase 2 'policy and program development'; Phase 2, Phase 3 involved 'implementation, adoption and scaling out'.
1116	Tull, K. 2019. Development, Climate and Environment: An Annotated Bibliography. K4D Helpdesk Report 644. Brighton, UK: Institute of Development Studies.	The information on climate change and resilience included in this report are taken from a variety of global sources. An assortment of peer-reviewed research and graphic/visual evidence is supplied. Online, local/country-based and international tools for monitoring and evaluation currently available for use are also highlighted. A section on gender also included, as it is a key issue that women will be more adversely affected by changes in climate and natural resources. Finally, a choice of potential solutions to dealing with various climate and environmental issues (as well as possible barriers to bear in mind), are listed, with supportive evidence.	Provide links to key international documents and videos on climate change and its mitigation and adaptation options. Includes a section on gender and climate change.

B2: Regional Documents

Database Ref. No.	Document	Summary	Key Lessons for NDC
1003	World Bank. 2017. Road Geohazard Management Handbook.	Defines types of geohazards, ground hazards, and water hazards. Not specifically climate. Outlines framework and methodology for risk assessment and adaptation measures. Focus on Asian region.	Outlines the background requirement for Law, Regulations and Standards and suggests levels of application. Flow charts of actions are included.
1011	Francisco. 2009. Climate Change Vulnerability Mapping for Southeast Asia. EEPSEA	Information on the sub-national areas (regions/districts/provinces) most vulnerable to climate change impacts in Southeast Asia. Definition of these vulnerable areas in a map for ease of reference of interested parties. Where: Vulnerability = f(exposure, sensitivity, adaptive capacity	Visual presentation of Vietnam with in assessments of regional climate related hazard and vulnerability
1025	ICEM. 2011. The Climate Change Adaptation and Mitigation Methodology, CAM	Climate change adaptation and mitigation methodology (CAM) developed specifically for the Asia Pacific region and has been extensively tested and adjusted in projects. The methodology combines a range of tools developed by ICEM and based on international and regional best practice.	Outlines an integrated approach to climate change mitigation and adaptation that recognises their close relationship. CAM addresses the need for a flexible and integrated approach to adaptation and mitigation planning that can be tailored to each situation and projects across all levels and systems.
1026	USAID. 2015. Mekong Adaptation and Resilience to Climate Change (USAID Mekong ARCC).	The key objective to increase adaptation capacity and resilience of communities to the negative impacts of climate change. The project undertook downscaled climate science modelling and then interpreted this in terms of specific impacts on eco and agrarian systems across the Basin. Input from communities to validate recent shifts in weather patterns.	Provides an example of downscaling climate modelling to local levels and its involvement in planning for mitigation and adaptation at local levels.
1042	ADB. 2014. Toward a Sustainability Appraisal Framework for Transport.	The ADB Sustainable Transport Appraisal Rating (STAR) is a tool for assessing the sustainability of ADB transport projects includes references to the issues of climate change and how climate impacts (floods etc) can be included in project appraisal.	Provides an example of project rating system that could provide lessons for developing a VN climate resilience assessment framework.
1045	ADB. 2009. The Economics of Climate Change in Southeast Asia: A Regional Review.	Reviewing and scoping of existing climate studies, climate change modelling, and national and regional consultations with experts and policy-makers. It examines how vulnerable S E Asia is to climate change, how climate change is impacting the region, what adaptation measures have been taken by the five study countries to-date. and how SE Asia can step up adaptation and mitigation efforts, and what the policy priorities are.	Summarises CC impacts across a wide spectrum of sectors Agriculture, Forestry, Coastal, Marine Resources, Health. Discusses both mitigation and adaptation options in general terms- with some specific examples as lessons to be learnt.

Database Ref. No.	Document	Summary	Key Lessons for NDC
1052	NDF World Bank. 2016. Climate Resilient Roads, Cambodia.	Best way to avoid damage caused by climate change are prevention and preparedness. Suitable methods for mitigation of various negative climate impacts on physical infrastructure are thoroughly described in this report together with supporting financial and cost & benefit analyses. Suitable methods for vulnerability mapping in general and vulnerability mapping of roads in particular are described, including a case study	Provides details on engineering adaptation options for roads. Discusses the role of planning and economic assessment. Provides advice and examples on economic analysis of CR adaptation options.
1060	World Resources Institute. 2016. Toward Decision-Relevant Information Systems for Adaptation to Climate Change in South Asia. DFID	This paper presents lessons and recommendations synthesized from recent research and convening activities supported by DFID under the project "Information for Climate Adaptation in South Asia: Identifying User Needs." This paper explores information as an input into adaptation decision making, mainly through a user-focused view of information, and user demand for information; considered from two main angles: Improving information and coping with imperfect information	Provides lesson to be learnt on (i) Improving information: and how do we ensure that this "must have" information exists and is made available to decision makers? (ii) Coping with imperfect information: how can decision makers best leverage existing information? What approaches to adaptation best help them avoid delay in action?
1064	World Bank 2018. The Second South Asia Regional South-To-South Learning Workshop on Building Resilience to Landslide and Geohazard Risk in Transport Sector. World Bank.	Report of workshop that focused on integrating geohazard disaster risk management, including resilient road asset management and disaster preparedness in each country's infrastructure program to help promote the safety of people within a sustainable transport sector as . The workshop is part of the "Building Resilience to Landslide and Geohazard. Risk in the South Asia Region" program.	Although focused on focused on overall disaster risk management, resilient road asset management and disaster preparedness in the transport sector, this document brings together DRM and CR together and demonstrates the importance of the links that need to developed.

B3: Selection of Key International Documents

Database Ref. No.	Document	Summary	Key Lessons for NDC
1001	WRA-PIARC. 2015. International Climate Change Adaptation Framework for Road Infrastructure.	Framework developed to guide road authorities through identifying relevant assets and climatic variables for assessment, identifying and prioritising risks, developing a robust adaptation response and integrating assessment findings into decision-making processes. The framework provides a life-cycle and iterative approach to climate change adaptation.	The framework facilitates the identification and replication of lessons learned from other countries and takes account of the varying levels of preparedness and adaptive capacity and knowledge from country-to-country and region-to-region. It is also designed to be applicable at any scale (such as national, regional, local or asset specific.
1002	ERA-NET. 2010. Risk Management for Roads in a Changing Climate. A Guidebook to the RIMAROCC Method	A concise methodological guide to risk management for roads regarding climate change in Europe. This should enable the user to identify the climatic risks and to implement optimal action plans that maximise the economic return to the road owner taking into account construction cost, maintenance and environment.	The method is designed to be general and to meet the common needs of road owners and road administrators in Europe. The method seeks to present a framework and an overall approach to adaptation to climate change. The method is based on existing risk analysis and risk management tools. Also provides a useful glossary.
1004	World Bank. 2014. Disaster Risk Management in the Transport Sector. A Practical Guidance Note. IMC Worldwide.	A guidance document for WB TTLs seeking to build the resilience of transport systems in donor countries. It sets out the principles of resilience in transport and examples of the practical measures can be included in projects to mainstream resilience across multiple domains and across the Disaster Risk Management (DRM) cycle.	This paper provides a roadmap illustration of how resilience can be included within the WB project cycle. It is noted that to develop practical and relevant guidelines require engaging with and understanding existing national decision making processes in more depth.
1112	ReCAP.2019. Climate Adaptation: Risk Management and Resilience Optimisation for Vulnerable Road Access in Africa: Engineering Adaptation Options Report. DfID-ReCAP.	Engineering and non-engineering adaptation options are presented. The crucial importance of effective drainage is highlighted. Adaptation techniques for handling the expected changes in temperature and precipitation, windiness, seal-level rise and more frequent extreme events are identified and discussed. These are specifically related to unpaved roads, paved roads, subgrade materials, earthworks and drainage within and outside the road reserve as well as possible implications for construction activities. The importance of timely and good maintenance practices is also highlighted and guidance given.	This Guideline highlights the impacts of different climatic impacts on road networks and suggests a range of engineering adaptation measures that can be implemented to overcome the problems. These can be implemented during the design phases of new roads or installed in existing infrastructure in response to potential problems arising from potential climate changes and available budgets

Database Ref. No.	Document	Summary	Key Lessons for NDC
1006	ReCAP. 2019. Climate Adaptation: Risk Management and Resilience Optimisation for Vulnerable Road Access in Africa: Climate Adaptation Handbook. DfID-ReCAP	Provides relevant information on climate adaptation procedures for rural road access, along with instructions on an appropriate methodology to address climate threats and asset vulnerability, to increase resilience for the foreseeable future. Detail regarding actual adaptation approaches and measures are included in the accompanying Guidelines covering Change Management (1177), Climate Risk and Vulnerability Assessment (1178), and Engineering Adaptation (1112)	This is an overarching document and illustrates the fundamental principles, processes and steps required for climate resilience.
1177	ReCAP. 2019Climate Adaptation: Risk Management and Resilience Optimisation for Vulnerable Road Access in Africa: Change Management Guideline. CSIR for DfID-ReCAP	The Guideline presented in this document acts as a supporting document to the Climate Adaptation Handbook (ref 1006) and aims specifically at providing change management guidelines relating to non-engineering adaptation options.	This document t covers policy and planning, stakeholder and asset management, and recommendations for the formulation of strategies and programmes for improvement. As such, this Guideline targets especially decision makers in government at national, provincial/state and district level.
1178	ReCAP. 2019. Climate Adaptation: Risk Management and Resilience Optimisation for Vulnerable Road Access in Africa: Climate Risk and Vulnerability Assessment Guideline. CSIR for DfID-ReCAP	The guideline document in hand is a supporting document to the Climate Adaption Handbook (ref 1006) and deals with climate risk and vulnerability assessments related to climate change adaptation. The purpose of this guideline is therefore to take the user through the process of gaining a comprehensive understanding of the main climate risks that may affect the road network and how these risks translate to an increased vulnerability of both the road network and the dependent population and economies. The guidelines focus on how these approaches will differ, given the scale of analyses conducted and the different role players, methods, tools and data needed to conduct such a risk and vulnerability study	This document takes users through the steps involved in conducting a risk and vulnerability assessment at national-/regional-level, as well as at local-/project-level risk and vulnerability study when implementing new or maintaining/retrofitting existing infrastructure. Flow charts and phased stages are listed.
1179	ReCAP. 2019.Climate Adaptation: Risk Management and Resilience Optimisation for Vulnerable Road Access in Africa: Visual Assessment Manual. CSIR for DfID-ReCAP	This manual is aimed at road authority staff in general and in particular persons responsible for assessing the vulnerability of road infrastructure to the impact of climate change. The impact of climate variability and change on roads may require that vulnerable sections of the road infrastructure are identified, and adaptations made to minimise potential future climate-related damage. t is, however, necessary to add to add climate vulnerability data to provide the required inputs for climate resilience assessments and the implementation of appropriate adaptation techniques to improve the climate resilience of the infrastructure.	The manual describes the nature and collection of climate vulnerability data, which is normally not part of the routine data collection for asset management purposes. This includes issues such as erosion, problem soils, drainage from the road and its near environment as well as from outside the road reserve, instability of embankments and cuttings, construction issues and maintenance problems. A standard form for recording the data is provided with a worked example and photos of the rated distresses F

Database Ref. No.	Document	Summary	Key Lessons for NDC
1034	Lwasa S. 2015. A Systematic Review of Research on Climate Change Adaptation Policy and Practice in Africa and South Asia Deltas.	A systematic review methodology was used to scan online knowledge portals for published papers and also unpublished government documents. The review characterizes the state of adaptation policy in African and South Asian deltas and identifies future research priorities targeting climate change adaptation in large delta regions. A large collection of relevant documents are referenced on-line.	This paper concludes that adaptation is biased toward development sectors and not integrated from household to community levels. Efforts are not properly mainstreamed in national-level policies for resilience building and transformational adaptation. The review shows that adaptation policy gaps exist surrounding knowledge advancement, scaling up actions, the "adaptation gap" and the move from incremental adaptation to transformational adaptation.
1038	De Souza et al. 2015. Vulnerability to Climate Change in Three Hot spots in Africa and Asia .	Key issues for policy-relevant adaptation and resilience building research. This serves as an overview to seven papers that are brought together in a special edition. This editorial introduction providing background on these hot spots, the program through which the studies were commissioned.	The analysis of this study shows that adaptation initiatives are being primarily driven at the national level, with apparent minimal involvement of lower levels of government or collaboration across nations. There is very little work to date cross-sector and actors to implement adaptation options and the private sector is absent in adaptation reporting.
1041	World Bank. 2016. How to Make Infrastructure Climate Resilient. IFC WB	Tools for PPPs in CR. Emerging markets, climate change threatens infrastructure that is critical for development. Because private companies and investors in emerging markets often manage infrastructure projects through public-private partnerships, they will now need to address climate change risks when planning and building these projects. The uncertainty of such risks has made incorporating them into project planning a challenge, but new tools and approaches, including insurance, are helping PPPs better respond to climate risks.	CR and PPPs. The challenge of incorporating climate risks into PPP contracts is that these contracts are currently ill suited to managing unpredictability. Ultimately financiers, governments, and insurers will need to come together to identify innovative new insurance products and approaches to deal with climate change risks.
1017	World Bank. 2017. Integrating Climate Change into Road Asset Management.	Overview and recommended processes and frameworks for the integration of climate adaptation into life cycle transport asset management. Challenges exist to research and academia in understanding climatic impacts on road networks better, developing more resilient technologies and, developing a better understanding to quantify the impact/benefits of climate adaptation strategies.	The long-term changes in average climatic indicators can be readily assimilated into the AM processes owing to the life cycle of many road assets being less than that of the time for significant change to occur. The main exceptions being around very long-life assets such as bridges. Leadership is required to facilitate and incentivise integration of CR into AM. There is a significant responsibility of road agencies and funding bodies to push for drastic changes that will allow for this integration.

Database Ref. No.	Document	Summary	Key Lessons for NDC
1046	UNFCCC. 2009. Climate Change: Impacts, Vulnerabilities and Adaptation in Developing Countries..	Outlines the impact of climate change in four developing country regions: Africa, Asia, Latin America and small island developing States; and also the vulnerability of these regions to future climate change; current adaptation plans, strategies and actions; and future adaptation options and needs.	For countries to understand their local climate better and thus be able to predict local climate change, they must have adequate operational national systematic observing networks, and access to the data available from other global and regional networks. A major problem in all regions is the limited capacity at regional and national level due to deficiencies in data collection and the lack of technical expertise.
1047	IPCC.2014. Climate Change 2014. Synthesis Report..	This Synthesis Report is based on the reports of the three Working Groups of the Intergovernmental Panel on Climate Change (IPCC), including relevant Special Reports. It provides an integrated view of climate change as the final part of the IPCC's Fifth Assessment Report (AR5).	The Synthesis Report distils and integrates the findings of the three Working Group contributions to the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC), Provides the primary evidence base on which CR strategies are based.
1051	Barrang-Ford L.,et al. 2015. Systematic review approaches for climate change adaptation.	Highlights innovative applications of systematic approaches, with a focus on the unique challenges of integrating multiple data sources and formats in reviewing climate change adaptation policy and practice. Presents guidelines, key considerations, and recommendations for systematic review in the social sciences in general and adaptation research in particular. Calls for increased conceptual and methodological development of systematic review approaches to address the methodological challenges of synthesizing and tracking adaptation to climate change. A strength of systematic approaches is that explicitly reported methods allow the quality and reliability of results to be reproduced and examined.	Present an analysis of approaches for systematic review and research synthesis and examine their applicability in an adaptation context. A strength of systematic approaches is that explicitly reported methods allow the quality and reliability of results to be reproduced and examined. Methods are discussed.

Database Ref. No.	Document	Summary	Key Lessons for NDC
1053	Barrang-Ford et al. 2015. The status of climate change adaptation in Africa and Asia..	The current status of adaptation in 47 vulnerable 'hotspot' nations in Asia and Africa, based on a systematic review of the peer-reviewed and grey literature, as well as policy documents, to extract evidence of adaptation initiatives. Adaptations are primarily being reported from African and low-income countries, particularly those nations receiving adaptation funds, involve a combination of groundwork and more concrete adaptations to reduce vulnerability, and are primarily being driven by national governments, NGOs, and international institutions, with minimal involvement of lower levels of government or collaboration across nations.	There is need for researchers, practitioners, policy makers, donors, and governments to identify and characterize the state of policies, measures and strategies designed to reduce the burden of climate change impacts, both as a means of evaluating the effectiveness of adaptation support, informing governance at various levels on adaptation needs, and justifying funding allocation. Targeted research may be needed in VN to further investigate the status of adaptation to inform potential prioritization of future adaptation financing.
1056	Qunitero J.D. 2010. A Guide to Good Practices for Environmentally Friendly Roads.	Part of an effort to provide sound, science-based information and advice on building practices for road construction. It documents good practices of roads built in a thoughtful, reduced-impact way. It promotes a more holistic, life-cycle approach to addressing impacts on nature, which is needed to break from the reactive, ad hoc approach that characterizes business as usual nowadays	Includes the best practices to be followed at each stage of the project cycle to integrate environmental considerations. Good practice smarter engineering has links to climate resilience.
1058	World Bank. 2013. Turn Down the Heat: Climate Extremes, Regional Impacts, and the Case for Resilience.	Summary of how of climate and weather extremes cause devastation and human suffering. Multiple threats of increasing extreme heat waves, sea-level rise, more severe storms, droughts and floods will have severe negative implications for the poorest and most vulnerable. This report extends this previous analysis by focusing on the risks of climate change to development in three critical regions of the world: Sub-Saharan Africa, South East Asia and South Asia.	Does not focus on the transport sector but provides a wider view of impacts and the need for increased resilience.
1059	World Bank, 2015. Moving Toward Climate-Resilient Transport: The World Bank's Experience from Building Adaptation into Programs.	This report reviews the World Bank's efforts and experience in building resilient transport systems. The tools and approaches are discussed: upstream sectoral and spatial planning to post-disaster risk and recovery support, from infrastructure system solutions and support to building an enabling environment—have all been piloted, and all contribute to reducing climate risks and increasing the resilience of transport systems. Way forward -mainstreaming the building of resilience in the transport sector will require a much more systematic approach.	Adaptive management measures that include monitoring infrastructure responses to changing climate extremes will need to be part of the transport's response. Maintenance regimes need to be adjusted and codes revised as needed The useful lifetime of some transport infrastructure is long and spans several decades from design to the end of its operational life. During that period, the climate may go through considerable change..

Database Ref. No.	Document	Summary	Key Lessons for NDC
1078	ERA-NET Road. 2009. State of the art of likely effect of climate on current roads.	Predicted climate changes will affect highways performance, If temperatures rise and precipitation increases, it looks as though present design theory and construction techniques must be amended. Cracking due to thermal effects; More rapid ageing increases embrittlement, with a consequent loss of waterproofing of the surface seal. Surface water can enter the pavement causing potholing and loss of surface condition. Links to research on temperature, water and road deterioration.	According to Austroads, the increase of costs caused by a change in climate will be much higher for the road users than for the owner, and this means that changes in road design and maintenance will be induced more by the user expectation than by the owner's response to climate induced damage
1080	GIZ. 2015. Impact Evaluation Guidebook for Climate Change Adaptation Projects.	This Guidebook supports project managers by providing an overview of different impact evaluation methods for climate change projects and how they can be applied to climate change adaptation projects. The application is illustrated by a case study of an adaptation project in Bangladesh. Rigorous Impact Evaluations (RIEs): involves the collection of a considerable amount of empirical data and make it possible to attribute observed changes to a particular intervention or at least quantify the contribution an intervention has made to these changes.	The Guidebook aims to provide 'hands-on' information, it contains a number of hints, definitions, practical examples, links to further reading material and checklists
1055	ADB. 2011. Guidelines for Climate Proofing Investment in the Transport Sector: Road Infrastructure Projects.	A guide project teams as they integrate climate change adaptation and risk management into each step of project processing, design, and implementation..	Encompasses lessons learned and good practices identified through several completed and ongoing ADB road projects. Part A: Climate Change and the Transport Sector; Part B: Climate Proofing Road Investment Projects; Part C: Building Adaptation Strategies into Policy and Sector Planning
1183	Vallejo, L. and M. Mullan (2017), "Climate-resilient infrastructure: Getting the policies right", OECD Environment Working Papers, No. 121, OECD Publishing, Paris. http://dx.doi.org/10.1787/02f74d61-en	This paper provides a framework for action aimed at national policymakers in OECD countries to help them ensure new and existing infrastructure is resilient to climate change. It examines national governments' action in OECD countries, and provides recent insights from professional and industry associations, development banks and other financial institutions on how to make infrastructure more resilient to climate change.	The document discusses the need to align spatial planning policies, national and international technical standards, and economic policies and regulation in support of infrastructure resilience. Governments may want to ensure international, national and local approaches are aligned in order to facilitate private-sector adaptation.

ANNEX C

Design, Construction and Maintenance Standards Review for Climate Adaptation

World Bank Support Team
Final Report Nov 2021

WORLD BANK GROUP

TABLE C.1. **Road design, construction and maintenance standards**

Article No.	Contents	Comments and Recommendations for Climate Adaptation
	TCVN 4054:2005	
	Risk analysis interaction between climate and climate change impact on the road network and on each road components.	There are no road design stipulations for analysing potential risks of flood, landslide, damages due to critical storm in TCVN 4054:2005. There are no stipulations for analysing potential risks of negative climate change impact on designed roads and structures in this standard. There are no supporting annex documents or guidance on the collection of statistic data and analysis to define the road sections at risk of flooding, landslide, or other damage due to climate change. The standard of TCVN 4054: 2005 needs to be updated in terms of incorporating climate change impact, analysis of interaction between climate and climate change impact on the road network and on road assets.
4.4	Median	The medians are introduced in the standard for from 4-lanes more than 4-lanes road without consideration of drainage in case of flooding. Below is a typical case on NH1 of concrete median obstructing flooding flow and make flooding is more serious in one side of the road. (Figure C.1-1)  Figure C.1-1: Flooding is more critical due to obstructed concrete medium.
7	Road embankment	Climate change impacts on road embankment as yet is not mentioned in this section. It needs to be included as a climate change impact factor to be taken into account on road embankment design for most regions of Vietnam.
8	Pavement structure and treated shoulder pavement	Climate change impacts on road pavement as yet not mentioned in this section. It needs to be included as a climate change impact factor on road pavement for flexible and rigid pavement structures together with supplemental stipulations for flexible pavement design and rigid pavement design.

Article No.	Contents	Comments and Recommendations for Climate Adaptation
7.3.2	The elevation of road embankment at drainage structures crossing low-land area should be least 0,5m higher than calculated water level corresponding to the design flooding frequency depend on the structures and road grade. In the special cases the road embankment elevation could be lower than the calculated value depends on designer proposal and decided by client.	The flood frequency given in Table 30 depends on structure type and road grade are not consistent and irrelevant with the construction standards of QCVN 01:2021 (issued 19/5/2021). There should be clearer technical criteria for special cases that designer can propose for lower elevation of road embankment that the calculated value. References from other standard (such as QCVN 01:2021) could be used for solution of the special cases. Guidance for "checking long-term stability of the drainage structures" in the special cases when using lower elevation should be provided in the annex of the standard or in separated design guideline as legal support documents.
7.3.3	The elevation of the pavement structure of subgrade must be higher than the calculated groundwater level (or permanent standing water level) as specified in Table 22"	Subgrade elevation is highly at risk of impact under climate change conditions depending on vulnerability analysis. The risk also depends on filling materials. The stipulation of 7.3.3 is not clear for specific cases of climate change impact vulnerability (flooding and elevation of underground water level), filling materials for embankment, subgrade thickness and material. Table 22 under 7.3.3 article should be improved to cover and to clear the impacts factor and specific cases.
9.3	Side drain	There is not any stipulation to consider increased rainfall, rain frequency for designing side drains. There are not any supporting documents as an annex (attached to the standard and/or guideline) for side drain hydraulic analysis and cross-section (dimensions) estimation of side drain depending on hydrological regime and hydraulic analysis. The stipulation of providing side drain when embankment height is lower than 0,6m might be not suitable for road sections which are highly impacted by climate change with increased rainfall and higher designed rain frequency.
9.4	Cut-off drain	There is not any stipulation to consider increased rainfall, rain frequency for designing cut-off drains. There are not any supporting documents as an annex (attached to the standard and/or guideline) for cut-off drain hydraulic analysis and cross-section (dimensions) estimation of cut-off drain depends on hydrological regime and hydraulic analysis. Stipulations on the collection of data considering climate change adaptation for hydraulic analysis of cut-off drain should be added in the standard.
9.5	Turn-out drain	There is not any stipulation to consider increased rainfall, rain frequency for designing turn-out drains. There are not any supporting documents as an annex (attached to the standard and/or guideline) for turn-out drain hydraulic analysis and cross-section (dimensions) estimation of turn-out drain depends on hydrological regime and hydraulic analysis. Stipulations on the collection of data considering climate change adaptation for hydraulic analysis of turn-out drain should be added in the standard.

Article No.	Contents	Comments and Recommendations for Climate Adaptation
9.6	Chute and cascade drain	There is not any stipulation to consider increased rainfall, rain frequency for designing chute/cascade drains. There are not any supporting documents as an annex (attached to the standard and/or guideline) for chute/cascade drain hydraulic analysis and cross-section (dimensions) estimation of chute/cascade drain depends on hydrological regime and hydraulic analysis. Stipulations on the collected data considering climate change adaptation for hydraulic analysis of chute/cascade drain should be added in the standard
9.7	Underground drainage works	There are not any supporting documents as an annex (attached to the standard and/or guideline) for chute/cascade drain hydraulic analysis and cross-section (dimensions) estimation of chute/cascade drain depends on hydrological regime and hydraulic analysis. The data for drain hydraulic analysis should consider climate change impact.
10	Bridges, culverts, tunnels and other structures crossing the flow	Climate change impact factors of increased rainfall, flooding frequency and sea level rise are as yet not mentioned in the standard. There are not any supporting documents as an annex (attached to the standard and/or guideline) for hydraulic analysis of bridges, culverts, and other drainage structures depends on hydrological regime considering climate change impact factors. Stipulations on the collected data considering climate change adaptation for hydraulic analysis of bridges, culverts drain should be added in the standard. The annex or guideline should be also supplemented.
	TCVN 5729:2012	
	Risk analysis of climate change impacts.	As with TCVN 4054:2005, there are not any stipulations for analysing potential risks of flood and landslide damage due to critical storm for designing a road. There are no supporting guidance documents attached as annex on collection of statistic data of climate change and on using the data for road design
		For expressways, in addition to the requirements mentioned in this standard, the design must comply with the basic requirements and design principles and other regulations mentioned in TCVN 4054:2005. Therefore, the contents considered and proposed in accordance with climate change for TCVN 5729:2012 are also selected as for TCVN 4054:2005 mentioned above.
	TCXD 104:2007 and QCVN 07- 02,04:2016	
	Risk analysis of climate change impacts	As with TCVN 4054:2005, there are no stipulations for analysing potential risks of flood and landslide damages due to critical storm for designing urban roads. There are no supporting guidance documents attached as annex on collection of statistic data of climate change and on using the data for urban road design Incorporating climate change impact factors of critical storm flooding, should be considered an integral component of urban road network and urban road infrastructure design The standard needs to be updated and improved or guideline for urban road design should be develop incorporating climate change adaptation in the same way to incorporating updated other standard, such as QCVN 01:2021.

Article No.	Contents	Comments and Recommendations for Climate Adaptation
		For urban roads, in addition to the requirements mentioned in this standard, the design must comply with the basic requirements and design principles and other regulations mentioned in TCVN 4054:2005, TCVN 5729:2012. . Therefore, the contents considered and proposed in accordance with climate change for TCXDVN 104: 2007 are also selected as for TCVN 4054:2005, TCVN 5729:2012 mentioned above.
14.3	Design of pavement structure	For urban pavement materials, it is necessary to have mandatory regulations and encourage for the use of recycled asphalt mixture (hot recycling and cold recycling), recycled concrete pavement, warm mix asphalt, in order to minimize exploitation resources, reduce greenhouse gas emissions and environmental pollution.
15	Urban drainage planning and urban planning elevations.	Urban drainage system: It is necessary to consider more specific regulations on urban drainage systems in areas affected by climate change with increased rainfall, increased frequency, and more floods. Especially urban areas in Mekong river delta that are heavily influenced by high tides and saline intrusion. A guideline to hydraulic analysis for urban drainage system using appropriate tool is needed to assess interaction between climate change factors and urban infrastructure system. Elevation of streets and intersections should be consistent with urban road drainage planning. There are still not any stipulations in the standard for climate change scenarios for roads and structure, nor a requirement for interactions between urban road and other urban infrastructure. .
16	Underground structures	There are not any stipulations regarding underground structures and climate change impact factors in the standard. The standard needs to be updated and improved to provide formal stipulations for designing urban underground structures which consider to potential climate change impact factors follow the specified climate changes scenario.
17.1	Tree and Greenery	There are still no stipulations regarding technical criteria and requirement of greenery corresponding to road/street grade in the urban area. It is necessary to update the standard with stipulation of greenery on urban road/street to respond to climate change, prevent noise, dust, heat and absorb toxic gases emitted by vehicles; improve and improve traffic conditions on the road: prevent glare from oncoming traffic.
	TCVN 10380:2014	
	Rural road – specification for design	As with TCVN 4054:2005, there are not any stipulations for designed low traffic rural road for analysing potential risks of flood and landslide damages due to critical storm. There are no supporting guidance documents attached as annex on collection of statistic data of climate change and on using the data for low traffic rural road design The standard needs to be updated to supplement stipulations on climate change adaptation.

Article No.	Contents	Comments and Recommendations for Climate Adaptation
5.5	Embankment	Stipulations of road embankments are not included with climate change impact factors. Road embankment stabilization and climate change impacts depends on regions; this is not mentioned in the standards. Design flood frequency for hydraulic analysis for embankment elevation and drainage structure size is defined in the standard based on the grade of low traffic rural road. However, incorporation of climate change impact factors still has not included. The standard should be updated by supplementing stipulations to define major climate change impact factors for low traffic rural road depending on climate regions, stipulations for deciding road embankment geometry, as well as embankment stabilization is related to grade of road, climate regions and specific road sections.
5.5.10	Drainage	Stipulations of drains system design for rural road includes side ditches, cut-off drains, turn-out drains, but still has no mention of climate impact factors of increased rainfall and critical storm and rain, flooding, increased temperature, sea level rising, saltwater intrusion. Consider the arrangement and size of culverts in accordance with increased rainfall volume, increased rainfall frequency, high floods, due to climate change and sea level rise and salinization.
5.6	Pavement	Climate change impact factors on pavement structure also are not mentioned in the standards. Information of target national program of new rural development could be considered.
6	Structures on the road	Climate change impact factors is not mentioned in the standards for major structures of bridges, culverts, embankment stabilization and protection.
	22TCN – 211 – 06	
	Flexible pavement structure – design specification	Input data of subgrade and unbound base and sub-base layer impacted by duration working under saturation is not stipulated in the standard. Strength data of asphalt layer impacted by high temperature and duration working under heating condition due to climate changes is not stipulated in the standard. Specific stipulation for surface and layer material selection consider climate change impact factors for typical regions are not provided in the standard. Input data of new materials and technologies of pavement for climate adaptation and climate change mitigation, such as modified asphalt, warm asphalt, porous asphalt and porous base layer, recycling materials, are still not updated. Pavement structure drainage incorporating climate data is not included in the standard As a whole, the standard needs to be updated and improved incorporating climate change impact factors.
1.4	Contents of flexible pavement structure design	Supplement the content of pavement structure drainage design with drain types and pavement structure with porous layers for drainage; data input and hydraulic analysis of the pavement structure drains.

Article No.	Contents	Comments and Recommendations for Climate Adaptation
1.5	Contents and requirement of survey for pavement structure design data input	Some contents and corresponding requirement should be added: • Specify climate change impact factors on flexible pavement structure • Specify surveying works for incorporating climate change impacts on input data: (i) subgrade and unbound base/ sub-base materials depends on working duration under saturated condition; (ii) strength of asphalt material based on temperature and critical temperature; (iii) new/modified materials properties for input data.
2.1	Pavement structure design principles	Principle of pavement design incorporating climate change impact factors should be added
2.2 to 2.7	Pavement structural design (Pavement structure layers selection)	Stipulations required for pavement structure layers selection and pavement drainage design considering climate change impacts. (
Annex B	Input data of subgrade	Update from available research projects on subgrade input data and the importance of saturation and its duration.
	TCVN 9845: 2013 Calculation of flood flow characteristics	
3	Term and definitions	Terms and definitions relating to climate change and climate change impacts factors and defined climate change scenario should be added.
5	Crest discharge, flood discharge, outflow flood hydrograph,	Supplement stipulations required relating to climate change impact factors on the flood flow characteristics. An annex or guideline for hydrologic calculation of crest discharge, flood discharge (including the use of rain frequency maximum daily rainfall depending on design rain frequency), outflow flood hydrograph integrating increased rainfall and impact of sea level rising should be supplemented in the standard or developed.
6	Define span of small bridge and culvert	Examples should be provided in the annex of standard for calculation/analysis steps to define span of a small bridge and culverts (one for each of pipe, box and arch culvert)
7	Define span of culvert considering flood at inlet	More details stipulations and annex of guidance should be provided, especially for section 7.10
	Define span of culvert considering tidal flow impact	Still missing from current version of the standard Stipulations and guidance should be supplement for another case of culvert span considering high water level at outlet (due to sea level rising or tidal flow impact)
	Define flood water level along road from outflow flood hydrograph or using analysis hydrological tool.	Annex or separated guideline for developing outflow flood hydrograph and defining flood water level along road and at structure locations from outflow flood hydrograph should be provided. Annex or separated guideline for using MIKE software to define flood water level (considering climate change impact factors)

Article No.	Contents	Comments and Recommendations for Climate Adaptation
	22TCN – 263 – 2000 – Road Survey Specification TCCS 31:2020 – Highway – Specification for Surveys	The standard has been over 20 years in use since before climate change was considered as global topical issue. The standard needs to be re-written, updated and improved TCCS 31:2020 has just been updated and issued, however, it has not included the climate change information and guidance of data collection and surveying works to collect and analysis climate change information and impact of climate change on road networks and road design works.
Part 2	Surveying works for pre-FS	There are no articles for surveying the climate change impact factors to incorporate pre-FS. It is required to supplement the climate change impact factors within the pre-FS, specifically: • Vulnerability of the studied road project with the climate change impact. • Data relating to the climate change impact factors for collection, in chapter 2 for topography survey, chapter 3 for hydrological investigation, chapter 4 for geological investigation, chapter 5 for socio-economic survey, chapter 6 for environmental survey. • Methods for collecting the data of climate change impact factors These regulations should also be included in the updated standard of TCCS 31:2020.
Part 3	Surveying works for preliminary design and FS	There are no articles on surveying the climate change impact factors to incorporate within FS. The proposal for surveying works incorporated climate change impact factors are similar for pre-FS above.
	TCVN 9436 : 2012 - Highway embankments and cuttings – Construction and quality control	Climate change impact factors have not been mentioned in the standard
11.2.2	Temporary construction road and bridge	The temporary construction road and bridge in areas seriously impacted by climate change require calculated elevation and/or stabilization of the road and size (span) of the culverts/bridges based on selected flood frequency.
11.2.6	Excavation of structures foundation and/or drainage canal	Safety requirements relating to the climate change impact factors should be included.
11.2.7	In water excavation	Cofferdam should be calculated incorporating the climate change impact factors.
	TCVN 8819: 2011 – Hot Asphalt Mix – Construction and quality control	
1	Application	There are no stipulations relating to climate change condition, despite highest temperature of pavement depends on high ambient temperature and daily heat duration. The stipulations for applying conventional hot mix asphalt should be improved for climate change.

Article No.	Contents	Comments and Recommendations for Climate Adaptation
	22TCN 356:2006 – Modified polymer hot asphalt mix – Construction and quality control	The standard needs to be updated Application conditions relating to increased maximum daily temperature and daily heat duration.
	Temporary guideline of other modified asphalt mix, porous asphalt.	The standards for construction and quality control or legally formal guideline should be developed based on the temporary technical guideline. Application condition relating to climate conditions should be included.
	Temporary guideline of asphalt recycling, warm mix asphalt.	The standards for construction and quality control or legally formal guideline should be developed based on the temporary technical guideline. Application condition relating to climate conditions should be included.
	TCCS 07: 2013 – Road routine maintenance specification	
4.2	Road management activities	The road maintenance includes checking road and structure condition before storm season and the damages after the storm. Assessment of climate change impacts for climate adaption road maintenance planning are not mentioned. Damages survey and assessment corresponding to climate data is required.
	Norm of Road Routine Maintenance No.3479: 2014	
Part 1	Road routine maintenance quantity	Climate change impact zoning should be undertaken. Higher norm of road routine maintenance quantity should be provided for the critical climate change regions, such as mountainous areas (North, Central Highland), central region and coastal.
Part 2	Norm of road routine maintenance	Requires adjustment to take account of climate change.
QLD.10100	Road patrol	Data on climate change and its impacts on road and structure damages for climate adaption road maintenance planning should be included
QLD.10300 & 10400	Periodic and emergency inspection for updating data of roads and bridges damages and storm and flood data	Climate change impact zoning should be made. Higher norm of emergency inspection and data collection should be provided for the critical climate change regions, such as mountainous areas (North, Central Highland), central region and coastal.

TABLE C.2. **Review bridge design standard (TCVN 11823:2017)**

<table>
<tr><th>Article No.</th><th>Contents (TCVN 11823:2017)</th><th>Comments and Recommendations for Climate Adaptation</th></tr>
<tr><td>Part 1</td><td colspan="2">TCVN 11823-1:2017 Highway bridge design specification – Part 1: General specification</td></tr>
<tr><td>1. 4.2.5</td><td>Extreme Event Limit States
Extreme Event Limit States must be considered to ensure the survival of the bridge during earthquakes or major floods or when hit by ships or vehicles, and also in erosion conditions.</td><td>For the Extreme Event Limit States, two factors related to the impacts of climate change, namely large floods and erosion conditions, have been mentioned.</td></tr>
<tr><td>Part 2</td><td colspan="2">TCVN 11823-2:2017 Highway bridge design specification – Part 2: General design and location features</td></tr>
<tr><td>2. 3.2.2.4 (*)</td><td>The pavement on the bridge must have anti-shearing and anti-rutting properties, good drainage and sufficient super-elevation conforming to TCVN 4054:2005</td><td>Obligatory and super-elevated drainage requirements must be in line with road design standards</td></tr>
<tr><td>2.3.3.1 (*)</td><td>Clearance: Updated according to inland waterway standards TCVN 5664 - 2009
Bảng 1 - Khổ giới hạn thông thuyền trên các sông có thông thuyền
<table>
<tr><th rowspan="3">Cấp đường sông</th><th colspan="3">Khổ giới hạn tối thiểu trên mức nước 5% [a] (m)</th></tr>
<tr><th colspan="2">Theo chiều ngang</th><th rowspan="2">Theo chiều thẳng đứng (trên toàn chiều rộng)</th></tr>
<tr><th>Cầu qua sông</th><th>Cầu qua kênh</th></tr>
<tr><td>I</td><td>>120 (>85)[b]</td><td>>75 (>70)</td><td>11</td></tr>
<tr><td>II</td><td>>60 (>50)</td><td>>50 (>40)</td><td>9.5</td></tr>
<tr><td>III</td><td>>50 (>40)</td><td>>30 (>30)</td><td>7</td></tr>
<tr><td>IV</td><td>>30 (>30)</td><td>>25 (>25)</td><td>6 (thích hợp)
5 (tối thiểu)</td></tr>
<tr><td>V</td><td>>25 (>20)</td><td>>15 (>15)</td><td>4 (thích hợp)
3,5 (tối thiểu)</td></tr>
<tr><td>VI</td><td>>13 (>10)</td><td>>10 (>10)</td><td>3 (thích hợp)
2,5 (tối thiểu)</td></tr>
</table>
[a] Xác định theo TCVN 5664: 2009
[b] Trị số ghi trong ( ) là áp dụng cho các cầu ở miền Bắc và miền Trung Việt Nam</td><td>This is an important update, related to Clearance, according to the provisions of TCVN 5664-2009 (TCVN 5664: 2009 replaces TCVN 5664: 1992.)
TCVN 5664: 2009 compiled by the Vietnam Inland Waterway Administration, Transport recommended, regulated by the General Department of Standards, Metrology and Quality, and published by the Ministry of Science and Technology.
It also is recommended to review and update TCVN 5664: 2009 taking into account factors due to climate change.</td></tr>
<tr><td>2.3.4(*)</td><td>ENVIRONMENT
The impact of the bridge and the bridge approach embankments on the local population, historical sites, arable land and sensitive areas in terms of aesthetics, environment and ecology must all be considered. Design must comply with all relevant environmental regulations. In accordance with National laws on the use of riverbanks, fish and wildlife habitats must be protected. The river geomorphology, the consequences of river bed erosion, the washing away of vegetation reinforcing the embankment must be considered, and in case of necessity, the effects on the tidal dynamics of the estuary must be considered.</td><td>The river geomorphology, the consequences of river bed erosion, the washing away of vegetation reinforcing the embankment must be considered, and in case of necessity, the effects on the tidal dynamics of the estuary must all be considered along within the context of climate change</td></tr>
<tr><td>2.4.2(*)</td><td>Study of topography
The current topographical map of the bridge must be established using contour maps and photographs. This study includes location history during the movement of land masses, soil erosion and river meandering.</td><td>This study includes location history during the movement of land masses, soil erosion and river meandering within the climate change context</td></tr>
<tr><td>2. 5.2.1(*)</td><td>The concrete of the bridge structure placed in sea water, above sea level and adjacent to sea water as well as industrial areas with harsh environment must be concrete with suitable anti-corrosion properties. Measures shall be taken to protect materials susceptible to damage from solar radiation and air pollution.</td><td>These are the necessary material requirements considering the climate and marine environment</td></tr>
</table>

Article No.	Contents (TCVN 11823:2017)	Comments and Recommendations for Climate Adaptation
2.5.2.1.2(*)	Structural arrangement of structural self-protecting details Where open joints are used, the bridge bearings must be protected against contact with salt water and debris.	Taking into account SLR and saline intrusion.
2.5.2.6	Deformation regulations. There are additional provisions for the deformation of straight beams on curved bridges and curved beams on curved bridges.	Climatic changes in temperature have an impact on structural deformation
2.5.2.6.2	Standard on deflection, supplementing the mandatory regulation to control the deflection of reinforced concrete slabs with three sides, and welded steel bridge decks. Additional regulations for calculating deflection for curved beams of section I and box section.	Potentially affected by climatic changes in temperature.
2.6.3(*)	Hydrological ANALYSIS The scale of the hydrological studies based on road grade should be determined according to the function, applicable law and flood hazard in the field. The issues should be adequately investigated in hydrological research: (i) To assess flood hazard and satisfy the requirements of wetland management; (ii) To assess risk to road users and assess damage to bridges and access overflow and/or erosive design flood; (iii) To assess flood disaster in high-risk areas – a test flood with an intensity selected appropriate to site conditions and perceived risks; (iv) To investigate and study the suitability of bridge foundations in erosion control; (v) To satisfy policy requirements and design criteria – Bridge Opening design flood and bridge erosion design flood for different road classes; (vi) Calibration of water levels and performance evaluation of existing structures - Historical floods; (vii) Assessment of environmental conditions - Information on basic or low-flow discharge and structures passing through the river mouth, tidal range; (viii) For projects that cross the marine/estuarine reserve areas, it is necessary to investigate and study the influence of tidal amplitude of sea level rise.	Floods need to be adequately investigated through hydrological research of climate change
2.6.4.3(*)	Bridge Opening The design process to determine the Bridge Opening should include assessment of flood distribution in the host stream and in the riverbank for current conditions, variation in flow rate. Combinations of road longitudinal alignments and bridge lengths to meet design objectives. • The effect of water level in the upstream of the bridge due to the bridge structure impeding the flow When using existing flood studies, their accuracy must be determined. The bridge size must be designed in accordance with the design flood of the Bridge Opening corresponding to the 1% flood frequency, unless otherwise specified. It is possible to choose a recurrence period of less than 100 years if there is an economic rationale (such as a 50-year flood or a 25-year flood for bridges on a secondary or lower grade road as specified in TCVN 4054: 2005).	The design process to determine Bridge Opening should include assessment of flood distribution in the host stream and in the riverbank for current conditions, variation in flow rate. Relevant future hydrological and flood related data must be used.

Article No.	Contents (TCVN 11823:2017)	Comments and Recommendations for Climate Adaptation
2.6.4.4.2 (*)	Bridge erosion As specified in Article 7.5, Part 3 of this set of standards, scour at bridge foundation is studied for 2 conditions: • Erosion due to design flood: design flood depth and local erosion due to design flood must be determined. i.e. flood equivalent to flood of frequency specified for bridge design, usually 100 year flood, except for small bridge works on local road. Design floods due to rain with high tide or mixed floods should be considered, which are usually more severe. In places where there is a need for dredging for waterway traffic, the overall erosion depth should consider the depth of river bed erosion over time due to the influence of dredging and other factors. • Test flood erosion: Stabilization of the bridge foundation must be studied for erosion conditions caused by sudden flood surges due to storm surges with high tides, or mixed floods that do not exceed 500-year floods or overflow floods with a period smaller recurrence period. Erosion due to flood control is used to control the bridge foundation at a special limit state.	In this set of standards, erosion at the bridge foundation is studied for 2 conditions Erosion due to design flood: design flood depth and local erosion due to design flood Requires climate change data input.
2.6.6 (*)	DRAIN SURFACE WATER The bridge deck and the bridge approach embankments should be designed to ensure safe and effective surface water drainage with minimal damage to the bridge and maximum safety for vehicular traffic. Bridge decks, including pavements, bicycle paths and pedestrian paths must be made with a horizontal or super high enough slope to allow good drainage in the horizontal direction. For wide bridges with more than 3 lanes in each direction, special design for surface drainage and/or special roughness may be required to reduce the possibility of vehicle rolling due to loss of friction. Water flowing down the roadway should be blocked from flowing into the bridge. The drainage ditch at the bridge approach embankments should be capable of draining all the collected water. In very environmentally sensitive cases where it is not possible to discharge water directly from the bridge deck to the river below, it is necessary to consider the solution of conducting water along a vertical drainage pipe attached to the bottom of the bridge span structure and discharging it into the river. fit on the natural ground at the bridge approach embankments.	The bridge deck and the bridge approach embankments should be designed to ensure safe and effective surface water drainage with minimal damage to the bridge and maximum safety for vehicular traffic. Requires climate change data input.
2.6.6.2 (*)	Design rainfall Design rainfall for bridge surface drainage must not be less than design rainfall for bridge approach embankments pavement drainage, unless otherwise specified.	Regulations on design rainfall, refer to the calculation method of US. Requires relevant Vietnam climate change data input.
2.6.6.3 (*)	Type, size and number of drain pipes The number of drain pipes should be kept to a minimum in accordance with hydraulic requirements. In the absence of other practical instructions, for bridges where the design vehicle speed on the road is less than 75 km/h, the size and number of drainage pipes should ensure that water does not flood half the width of any lane. which car. For bridges where the design vehicle speed on the road is not less than 75 km/h, it is necessary to ensure that water does not flood any part of the lane. The trench should be blocked at the slope change to prevent water from flowing over the deck. The drain hole or sump of the deck must be sufficient for drainage and easy to clean. The minimum internal size of the common drain pipe should not be less than 100mm	The number of drain pipes to be kept to a minimum in accordance with hydraulic requirements Requires relevant Vietnam climate change data input.

<table>
<tr><th>Article No.</th><th>Contents (TCVN 11823:2017)</th><th>Comments and Recommendations for Climate Adaptation</th></tr>
<tr><td>2.6.6.4 (*)</td><td>Draining water from the bridge deck drain pipe
The deck drainage pipe shall be designed and installed so that water from the deck or pavement is directed away from the members of the superstructure and the substructure. If there are no special requirements for testing water released from drains and pipes, consideration should be given to:</td><td>Detailed requirements for the Bridge Surface Drainage Pipe -requires relevant Vietnam climate change data input.</td></tr>
<tr><td>2.6.6.5 (*)</td><td>Structural Drainage
The holes in the structure are likely to collect water, it is necessary to place the drainage hole at the lowest point. The bridge deck and deck cover must be designed to avoid water stagnation, especially at the bridge deck joints. For bridge decks with non-uniform coating or decks with formwork left, it is necessary to find a solution to drain the water that may accumulate on the adjacent surface.</td><td>Structural drainage requirements need to place the drainage hole at the lowest point
Requires relevant Vietnam climate change data input.</td></tr>
<tr><td>Part 3</td><td>TCVN 11823-3:2017 Highway bridge design specification – Part 3: Loads and load factors</td><td></td></tr>
<tr><td>3.4</td><td>Load factors and load combinations/combinations
- Redefining the intensity state II. (bridge design standard 22TCN272-05 does not stipulate this strength state) is a combination with vehicle load type according to the use requirements of the Owner. - Additional regulations on the use of load combinations when assessing general stability.</td><td>Consider the effects of loads on bridge structures such as wind load and temperature effects requires relevant Vietnam climate change data input.…</td></tr>
<tr><td>3.8</td><td>WIND LOAD: WL AND WS
Bảng 13 - Các giá trị của V_B cho các vùng tính gió ở Việt Nam
<table>
<tr><th>Vùng tính gió theo TCVN 2737 - 1995</th><th>V_B(m/s)</th></tr>
<tr><td>I</td><td>38</td></tr>
<tr><td>II</td><td>45</td></tr>
<tr><td>III</td><td>53</td></tr>
<tr><td>IV</td><td>59</td></tr>
</table></td><td>Wind regulations need to be researched and updated in accordance with climate change scenarios.</td></tr>
<tr><td>3.12.</td><td>Temperature
- Regulating the temperature in table 3.12.2.11 is the range of temperature fluctuations, not the spherical temperature amplitude as in the 1998 version, causing confusion.</td><td>In the future, Part of temperature regulation need to updated to appendix. Requires relevant Vietnam climate change data input.</td></tr>
<tr><td>3. 11.2.1 (*)</td><td>Temperature range
Bảng 24 - Biên độ nhiệt độ**
<table>
<tr><th>Vùng khí hậu</th><th>Kết cấu bê tông</th><th>Mặt cầu bê tông trên dầm hoặc hộp thép</th><th>Mặt cầu thép trên dầm hoặc hộp thép</th></tr>
<tr><td>Bắc vĩ độ 16°B (Đèo Hải Vân)*</td><td>+5° C đến +47° C</td><td>+1° C đến +55° C</td><td>-3° C đến +63° C</td></tr>
<tr><td>Nam vĩ độ 16°B (Đèo Hải Vân)</td><td>+10° C đến +47° C</td><td>+6° C đến +55° C</td><td>+2° C đến +63° C</td></tr>
<tr><td colspan="4">* Đối với các địa điểm ở phía bắc vĩ độ 16° B và ở độ cao cao hơn mặt biển trên 700m nhiệt độ thấp nhất trong bảng phải trừ bớt 5° C.
** Biên độ nhiệt độ cầu xác định theo Bảng là dựa trên biên nhiệt độ không khí trong bóng râm từ 0°C đến +45°C phía bắc Vĩ tuyến 16° N (Hầm Hải Vân) và từ +5°C đến +45°C phía nam vĩ tuyến 16° N. Khi xác định được các dữ liệu nhiệt độ tại vị trí công trình, có thể sử dụng chúng để xác định giá trị lớn nhất và nhỏ nhất của nhiệt độ không khí trong bóng râm với chu kỳ lặp là 100 năm cho vị trí công trình, và có thể điều chỉnh nhiệt độ của cầu trong Bảng tương ứng .</td></tr>
</table></td><td>Consider updating the temperature boundary table
The temperature at the bridge site uses the air temperature in the shade with a 100-year repetition period for the building site
This is a factor to consider and adjust in the future</td></tr>
<tr><td>Part 4</td><td colspan="2">TCVN 11823-4:2017 Highway bridge design specification – Part 4: Structure analysis and evaluation</td></tr>
</table>

Article No.	Contents (TCVN 11823:2017)	Comments and Recommendations for Climate Adaptation
4.6.2.7 (*)	Distribution of horizontal wind loads in bridge girder system	Horizontal wind load requirements in the girder system requires relevant Vietnam climate change data input.
4. 6.6 (*)	TEMPERATURE GRADIEN ANALYSIS When the determination of the internal force due to a vertical thermal gradient is required, the analysis should take into account axial elongation, bending strain and internal stresses. The gradients must comply with Article 11.3 Part 3 of this standard.	Requirements for determination of internal force due to thermal gradient needs relevant Vietnam climate change data input.
4. 7.2.2 (*)	7.2.2 Oscillation due to wind 7.2.2.1 Wind speeds For critical structures sensitive to wind effects, the location and magnitude of the extreme pressure and suction values should be determined by wind tunnel tests. 7.2.2.2 Kinetic effects Wind-sensitive structures must be analysed for dynamic effects such as turbulence or gusts, and wind-structure instability such as jolts and wobbles. Thin or pliable structures should be analysed for buckling, over-lifting, and progressive deflection. 7.2.2.3. Structural design solutions Vibratory deformation under wind action can lead to excessive stresses, structural fatigue, and inconvenience or inconvenience to the user. The bridge deck, cable-stayed and cable-stayed cables must be protected from excessive turbulence and fluctuations due to wind and rain. In practical application, the use of dampers should be considered to control excessive dynamic effects. When damper settings or shape change are not possible, the structural system must be altered to achieve that control.	Scientific studies are needed to supplement the effects of climate change, especially for large cable-stay bridges
Part 5	TCVN 11823-5:2017 Highway bridge design specification – Part 5: Concrete structures	
5.4.2.1	Cement content has more specific regulations for high performance concrete (HPC): the amount of cement does not exceed 593Kg/m3 expanding the use of high limit reinforcement 690 MPa and high compressive strength concrete (70 MPa and 105 MPa)	Consider the impact of climate change on material performance
5.4.2.3	Creep and shrinkage: specifying shrinkage and creep characteristics can be applied to concrete with compressive strength up to 105MPa. - The coefficients from the shrinkage variable change completely.	Consider the impact of climate change on material performance
5.6.2 (*)	THE EFFECT OF FORCED DEFORMATION The effects of forced deformation due to shrinkage, temperature change, creep, prestressing and bearing displacement must be considered.	Effect of forced deformation due to shrinkage, temperature change
5.7.3.6 (*)	Deformations 7.3.6.1 General The provisions of Article 5.2.6 Part 2 of this standard shall be complied with. Expansion joints and bearings must accommodate dimensional variations caused by loads, creep, shrinkage, temperature changes, cylindrical settlement and prestressing.	Expansion joint strains and bearings must be accommodated for dimensional variations caused by loads, creep, shrinkage, temperature changes, cylindrical settlement and post-tensioning.

Article No.	Contents (TCVN 11823:2017)	Comments and Recommendations for Climate Adaptation
5.10.8 (*)	REINFORCEMENT TO WITHSTAND SHRINKAGE AND TEMPERATURE Reinforcement to withstand shrinkage and temperature stresses should be placed near concrete surfaces exposed to daily temperature changes and in bulk structural concrete. Reinforcing heat and shrinkage must be arranged to ensure that the total reinforcement in exposed surfaces is not less than specified in this Article. Shrinkage and temperature resistant reinforcement can be arranged with bars, welded wire mesh panels or prestressed steels.	Regulations on reinforcement for shrinkage and temperature require relevant Vietnam climate change data input.
5. 14.2.3.5 (*)	Thermal effects during construction Thermal effects that may occur during bridge construction must be considered. The temperature variation for bearings and expansion joints shall be stated in the design documents.	Requirement for the temperature variation of bearings and expansion joints needs relevant Vietnam climate change data input.
PART 6	TCVN 11823-6:2017 Highway bridge design specification – Part 6: Steel structures	
PART 9	TCVN 11823-9:2017 Highway bridge design specification – Part 9: Deck and deck systems	
9.8.3.3 (*)	Surface coating on the bridge The deck coating should be considered as an integral part of the orthogonal deck system and shall be bonded to the steel deck of the deck.	Regulations on coatings on the bridge deck, there should be studies to adjust to climate change.
PART 10	TCVN 11823-10:2017 Highway bridge design specification – Part 10: Foundations	
	The entire section 10 was rewritten on the basis of updating new research results on the reliability coefficient for the foundation.	Requires relevant Vietnam climate change data input.
PART 11	TCVN 11823-11:2017 Highway bridge design specification – Part 11: Abutments, piers and wall	
	Entire section 11 has been changed, in the 2002 research report period the entire chapter has been rewritten.	Reviewing regulations on protection of structures against erosion caused by rain and floods . Requires relevant Vietnam climate change data input.
11.5.2 (*)	SERVICE LIMIT STATES General When designing a foundation at the service limit state, the following issues must be considered: • Subsidence • Horizontal displacement • Overall stability, and • Erosion corresponding to the design water level.	Erosion corresponding to design water level requires relevant Vietnam climate change data input.
11.5.5.3 (*)	Extreme Event Limit States Foundation Erosion The design of the foundation must have the nominal resistance after the erosion caused by the calculated flood and check according to Articles 6.4.4.2 Part 2 of this standard and 7.5 Part 3 of this standard and ensure the following resistance. scour withstands insufficient strength combined loads and equal resistance coefficients. With the uprooting resistance of piles and drilled piles, the resistance coefficient is taken to be 0.8 or less. Foundation structures not only account for loads placed on the structure but also for any type of loads and drifts that occur during the flood.	For Extreme Event Limit States Foundation structures are not only counted with loads placed on the structure but also any type of loads and drifts that occur during floods. Requires relevant Vietnam climate change data input.

Article No.	Contents (TCVN 11823:2017)	Comments and Recommendations for Climate Adaptation
11.7.3.6 (*)	Erosion The effect of scour should be considered when selecting the pile depth and nominal pile resistance when driving. The pile foundation shall be designed so that the deep burial of the pile after scouring with the design scour value ensures the required compressive strength and nominal lateral resistance. Pile foundations must be designed to withstand the impact of drifting during the flood season along with other forces acting on the foundation.	Erosion Pile foundation must be designed to withstand the impact of drifting during the flood season along with other forces acting on the foundation. Requires relevant Vietnam climate change data input.
PART 12	TCVN 11823-12:2017 Highway bridge design specification – Part 12: Buried structures and tunnel liners	
12.6.5 (*)	Erosion The inclusion structure shall be designed in such a way that no structural part will cause displacement due to erosion. When a risk of erosion is anticipated, the flange wall should be stretched long enough to protect the structural part of the soil surrounding the structure. For structures located on easily eroded sediments, it is necessary to use retaining walls placed deep below the maximum possible erosion depth or paving the bed. The foundation of the structure must be placed at least 600mm below the maximum expected erosion depth.	Erosion requirements design the inclusion structure so that no structural part will cause displacement due to erosion and hence requires relevant Vietnam climate change data input.
12.6.8 (*)	Treatment of culvert header 6.8.1 General Special attention must be paid to the structure to protect the toe roof of the culvert at the top of the culvert, where there is standing water or possible erosion or a push to lift the top of the culvert.	Requirement on structure to protect the toe roof of the culvert at the top of the culvert, where there is standing water or possible erosion or a push to lift the top of the culvert . Requires relevant Vietnam climate change data input.
PART 14	TCVN 11823-14:2017 Highway bridge design specification – Part 14: Joints and bearings	
14.4.1 (*)	General The selection and arrangement of expansion joints and bearings shall take into account deformations due to temperature and other time-dependent causes and shall be appropriate to the specific function of the bridge.	Consider the above in terms of temperature changes
14.4.2 (*)	DESIGN REQUIREMENTS The minimum thermal displacements shall be calculated from the extreme temperatures specified in Clause 11.2, Part 3 of this standard and the expected installation temperature. The design loads shall be based on the load combinations and load factors specified in Part 3 of this standard.	It is proposed in the future to have research on temperature extremes in the design of bridges to adapt to climate change.
14.5.1.4(*)	Material Materials must be selected to ensure that they are elastically, thermally and chemically compatible. Where strength differences exist, material face-to-face connections must be constructed to provide fully functional systems. Materials, other than plastics, should have a service life of not less than 100 years. Plastics for expansion joint sealants and chutes should have a service life of not less than 25 years. Expansion joints subjected to traffic loads require a non-slip surface treatment and all parts must be resistant to abrasion and vehicular impact.	The requirements of the joint materials must be selected to ensure that they are elastically, thermally and chemically compatible Requires relevant Vietnam climate change data input.

ANNEX D

Technical Issues from Key Informant Interview

Interviewer: Ms. Tran Thi Kim Dang - NDC - Climate Adaptation team member
Interviewee: Mr. Doan Duc Cuong - Hydrological Expert - TEDI Senior Advisor

World Bank Support Team
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E.1 List of documents provided by Mr. Doan Duc Cuong and the summary

Ord.	Documents	Summary
1	Hydrological Analysis report for Ho Chi Minh road, section Kien Binh – My An	The report includes hydrological calculation and analysis for Kien Binh – My An section of Ho Chi Minh road using VRSAP software (Vietnam River Systems and Plains). Results are flood distribution map (in area of the section) and proposed flooding control.
2	Assessment of flood drainage when upgrading National Highway 1A in typical river basins – Hydrological Calculation and Analysis report.	The report provides hydrological calculation and analysis to assess flood drainage in basins of Tra Bong in Quang Ngai province; Vu Gia – Thu Bon river in Quang Nam & Da Nang using MIKE software. Results are flooding situation includes number of flooding section, the length of roads under flood, flood water level and flooding hours, the water velocity and flow discharge.
3	North – South Eastern Expressway (2017-2020), section of NH 45 – Nghi Son – Hydrological Analysis Report	The report provides hydrological analysis using MIKE software to assess flood situation corresponds 9 scenarios of combination of scope of work and designed flood frequency. Expressway and drainage structures on the design alternative and North-South existing railway were incorporated in the hydrological analysis to assess flooding condition
4	Selection of Road Slope Protection Measures	The paper by Doan Duc Cuong introduces and summarizes contents of "Guideline of Road Slope Protection Works" from Nepal for lessons to be learnt in Vietnam. Matrix of landslide features road slope protection measures is provided for possible application
5	Lessons of hydrological survey and hydraulic calculation from NH1 project implementation for North – South Expressway (Ha Noi – Can Tho) project	The paper by Doan Duc Cuong provides experiences and lessons for hydrological survey and hydraulic calculation from NH1 project implementation feasibly to be apply for North – South Expressway (Ha Noi – Can Tho) project

E.2 Technical issues for discussion/ questions for key informant interview

1. Flooding flow characteristics in the regions of Vietnam and climate change impacts

2. Influence of existing key routes of Ho Chi Minh road, National Highway 1, North-South railway on flooding flow variation and floods distribution

3. Lessons to be learnt for road network planning in general and for the North-South routes planning of Vietnam such as North-South expressway and further as North-South high-speed railway, coastal roads.

4. Regarding the design of sea dyke combined with road and/or coastal road system, how the coastal road system could be assessed integrated with other existing and planning systems mentioned above (HCM road, national highway 1, North – South railway, high-speed railway; North-South expressway) as key factors which make changes of flood distribution, flooding drainage.

5. What is effective method to integrate climate change condition in road network planning and road work solutions?

6. Recommendations could be for road network planning in general and particularly in terms of road drainage system, hydrological survey and hydraulic analysis of drainage works?

7. What are the difficulties (for survey and design) in using the design standards (previous and current) related to hydrology and hydraulic calculation of drainage structures? Risks that cannot be controlled in the survey and design works currently when using the current design standards.

8. There have been some improvements in the professional standard for hydrologic survey, what should be added and/or improved according to the expert's experience?

9. Discuss on inadequacies in survey work for hydrological design in the road projects in Vietnam and solutions.

10. An expert's point of view in separating two types of documents: standards (which provide requirements and are mandatory); and guidelines (which provide how-to and/or recommendation or suggestion), which are both legal documents could be applied for Vietnamese standards system?

11. Are the current handbooks, manuals and/or guidance for hydraulic calculation of bridge, culverts, and spillway sufficiently and appropriately for designers to perform the designs? For big bridges, is the hydrological calculation of bridge works different from previous methods (methods from in the 80s follows Russian standard)? Is it necessary for an updated or new handbook of hydrologic survey and hydraulic calculation and analysis for drainage structure design?

E.2 Photographs of the Seminar in Road & Highway Dep. of UTC based on the key informant interview

ANNEX E

Working Papers by Team Members

World Bank Support Team
Final Report Nov 2021

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WORKING PAPER 1 CLIMATE AND THE ROAD INFRASTRUCTURE SYSTEM IN VIETNAM

Author: Tran Thi Kim Dang

1. How road infrastructure system in Vietnam has been impacted by climate change?

According to the National Plan[1]: the annual average temperature of the country has increased by about 0.62°C over the past 50 years; Sea level increased by about 3.34 mm/year in the period 1993 - 2014; Natural disasters increase in both intensity and frequency.

RCP8.5 and RCP6.5 scenario is proposed to apply in transportation infrastructure planning and design based on the infrastructure scale. According to the Climate Change Scenario 2016 issued by Ministry of Natural Resources and Environment and follows the RCP8.5, to the end of 21th century: the annual average maximum temperature increases from 3.0 to 4.8 ^{0}C depends on regions; Annual rainfall tends to increase with the highest increase could be over 20% in most of the North, Central Region, part of the South and Central Highlands; and sea level is increasing results in, loss of coastal protection forests, gradually narrowing agricultural land areas, saline intrusion, flooding and flood tide.

In the process of planning, designing, constructing, and exploiting road transport infrastructure, natural and climate conditions such as temperature, precipitation, sea water level, water flow velocity, could be taken as input data for hydrological and structural analysis for stability and sustainability of designed roads and structures. Consequences of climate change are serious for on-going operation of the roads and structures.

The notable potential impacts include: (i) More frequent/severe flooding interrupts traffic, especially at the underground tunnels and low-lying infrastructure, or requires effective drainage and pumping, due to more intense precipitation, sea level rise, and storm surge. (ii) Increased numbers and magnitude of storm surges and/or relative sea level rise potentially shorten infrastructure life. (iii) Increased thermal expansion of paved surfaces, potentially causing degradation and reduced service life, due to higher temperatures and increased duration of heat waves. (iv) Higher maintenance/construction costs for roads and bridges, due to increased temperatures, or exposure to storm surge. (v) Asphalt degradation and shorter replacement cycles; leading to limited access, congestion, and higher costs, due to higher temperatures. (vi) Culvert and drainage infrastructure damage, due to changes in precipitation intensity (vii) Decreased driver/operator performance and decision-making skills, due to driver fatigue as a result of adverse weather. (viii) Increased risk of vehicle crashes in severe weather. (ix) System downtime, derailments, and slower travel times, due to rail buckling during extremely hot days. (x) Restricted access to local economies and public transportation.

1 The National Plan for Climate Change Adaptation - Period 2021-2030, Vision to 2050 of Vietnam government.

Typical and detailed climate impacts on the road transportation structures are follows:

i) Increased precipitation

Increased precipitation and critical rainy is the most important factor of climate change in Vietnam. The annual rainfall as reported in the National Plan for Climate Change Adaptation is over 20% and the critical rainy is much more serious in some figures from typical rain measuring stations in central region.

Critically heavy rains over large areas with severe loss of vegetation, especially when combined with the discharge of hydroelectric power plants, have caused severe flooding. Drains, culverts and flows below bridges are blocked due to mud, soil, rocks, garbage, drifting trees. Flash flood washes out road segments or causes land sliding and/or muddy flowing. Road pavement are damaged seriously after flooding due to surface erosion, loss of surface pavement, and saturated pavement materials and subgrade.

ii) Increased storms/disasters

Hurricane often cause heavy rain and so is the impact of landslides and flash food in the mountainous areas and flooding in flat areas which have been presented in the previous section. Unusual wind patterns and intensity may cause damage to other technical infrastructure of the road such as signs, street lights, trees; affecting bridge works (mainly cable-stayed bridges) and causing traffic insecurity. In general, the impacts of natural disasters of storm mainly cause losses to the road and road structures and road furniture facilities. The most serious impact of critical storms or disaster is flood in lowland and flash flood in mountainous areas. Changing of the storm frequency and intensity brings critical conditions to road infrastructure which has not and hardly incorporated in road works design, construction and maintenance process.

iii) Increased temperature

Increasing daily temperature, number of continuous hot days and average ambient temperature causes many technical issues and damage to pavement and road structures. Typical damages of road pavement in hot weather is wheel rutting. Shorten pavement life is a serious technical issue due to binder aging of asphalt pavement and high thermal stresses occurred in concrete pavement slab.

iv) Sea-level rise impacts and hazards

Sea-level rising impacts at different features in regions of Vietnam. While the impact seems light in the North due to wide branching river system it is more serious in the central due to special terrain condition of short flowing distance and very steep slope when combined with tidal flow to reduce flowing capacity of drainage structures. The most serious impacts are in the low-land Mekong delta in the South (where the sea-level rising combined with heavy rain and tidal flow result to more serious flooding.

Data of water level in major rivers in Mekong delta show continuously critical increase due to tidal flow. Maximum water level in Can Tho gauging station is only 1,54m in 1977 increased up to 2,23m in 2018, 2,25m in 2019 and 2,18m in 2020 (It is very similar increasing trend of water level in the major rivers of Mekong delta system

2. How is existing road infrastructure system in Vietnam challenging to climate change?

Transport infrastructure system is damaged seriously after floods and critical storms. Landslides destroy or close road, and flash flood sweep away bridges and culverts. Flooding over roads over a long time soften pavement materials leading to raveling and washed out. Effective measures for a climate resilient transport infrastructure system has not been approached practically. It is a fact that inappropriate and/or insufficient solutions of road network planning, designing, and building make the impacts of climate change more critical.

Key informant interview has been mobilized unofficially with a hydrological expert from TEDI (Transport Engineering Design Institute) under seminar and followed by discussion. Technical issues and questions were raised during the interview to focus on how the existing road infrastructure in Vietnam is challenged by climate change are summarized as follows.

i) *Climate conditions included climate change has serious impacts on transport infrastructure and impact level conversely are influenced by the transport infrastructure. The road infrastructure system and road works therefore could be planned, designed, and built by the way to make the impacts less. Inter-actions impact analysis between the climate change conditions and the infrastructure is necessary for decision making*

An example describes water level along Thu Bon river basin from upstream to the see which is impacted by existing transport infrastructure includes NH 14B, Thong Nhat railway, NH 1A and the planned North – South expressway. The expressway has a much larger bridge aperture of 3058m compared with 2067m than the one on Thong Nhat railway results to lower overflow. It could be found that Thong Nhat railway causes severe flooding upstream. The flooding would be different in case of other routes as in the long-term transport planning of high-speed railway and coastal road/ sea dyke and depends on the design option.

ii) *Hydrological modelling and hydraulic analysis can be used to present clearly existence of inter-impaction of climate change and transport infrastructure system corresponding to strategic planning or design scenario to support decision making*

Hydrological modelling (NAM model) and hydraulic analysis tool (MIKE 11) for flood drainage of Tra Bong river basin in Quang Ngai province and Vu Gia – Thu Bon river basin in Quang Nam province for NH1 upgrade project. The analysis results help technical appraisal for feasibility study and design alternative selection.

North – South Eastern Expressway (2017-2020), NH45 - Nghi Son section feasibility study covers 9 scenarios of combination of designed solution and designed flood frequency were used for technical appraisal. Existing infrastructures such as dyke sections and road, the expressway and designed drainage structures on the route were incorporated in the hydraulic analysis to assess flooding condition of Yen river in Thanh Hoa province. The results are maximum water level which were used for making decision of technical design solution which is climate adaptation.

iii) *Hydrological survey and hydraulic analysis for road design in many projects are still insufficient. Inadequacy and shortcomings are reviewed and discussed for lessons to be learnt*

Inadequacy of hydrological survey for designing flood-bypass road in Ai Nghia town of Quang Nam province results to serious damages which make the road unfunctional during flood.

The shortcomings of surveying work for hydraulic calculation and analysis are at:

- Preparation prior surveying works to collect meteorological and hydrological data from available documents for historical flood levels.
- Poor hydrological investigation results to incorrect flooding appearance year and inaccurate hydraulic calculation and analysis
- Inappropriate selection of location for hydrological investigation results to unreliable data and confusing historical flood levels
- Hydrological survey as in current standard required only historical flooding water level, but not: causes of the flood and flood evolution; characteristic of flooding flow with falling rocks, fallen trees or mud; influence if any of tidal flow; erosion at upstream and downstream; overflow at downstream which could make hydraulic analysis short-sighted.
- Hydrological survey along flooded road section as in current standard also required only flooded water level, but not: flooding duration and traffic interruption duration; flood depth; location and direction of overflowing and subjectively estimated overflow of swift-flowing, medium or calm flowing compared with erosion and/or landslide occurrence.
- There is not specific guidance for hydrological survey at typical terrain, for example of mountainous to require flow characteristic with rolling rocks and mud, or of flat at river mouth to require tidal flow direction and frequency.
- Hydrographic engineer and functional tasks of surveying to collect necessary data for hydrological modelling and hydraulic calculation and analysis, providing the analyses and controlling reliability of the collected data rarely are required as key and separated staffs in a transport project.

WORKING PAPER 2 HOW DOES EXISTING DOMESTIC LEGAL DOCUMENTS SYSTEM SUPPORT TO CLIMATE ADAPTATION DESIGN AND CONSTRUCTION OF ROAD PROJECTS

Author: Tran Thi Kim Dang

National legal documents include standards which could support to climate adaptation has been reviewed by all team members. There are number of standards for road infrastructure design, construction and maintenance which are relevant and potentially support to climate adaptation .

Flood prevention in road design is controlled at sections of roads whose foundations are regularly flooded, along rivers and streams, and at drainage works: bridges, culverts, spillways, etc. In addition to some general regulations included in the general road design standards, another key standard (TCVN 9845:2013), provides regulations for the hydraulic analysis of the drainage structures on the roads.

Some articles from the standards which are relevant to hydraulic calculation and climate adaptation are extracted as follows.

TABLE 1. **The relevant contents in TCVN 4054:2005 and articles in TCXD 104:2007 for hydraulic analysis**

Structures	Road category		
	Expressway	Grade I,II	Grade III to VI
Embankment	Follows designed flood frequency of drainage structures		
Medium and large bridges	1	1	1
Small bridge and culvert	1	2	4
Cut-off and side drains	4	4	4

Article 9.3.8, TCVN 5729:2012

9.3.8 Design rainy frequency for hydraulic calculation of drains is 4%, and 1% for bridges and culverts.

Article 13.2.2, TCXDVN 104:2007

13.2.2. The design road elevation in urban areas must be consistent with the controlled construction elevation in the formal urban plan. In case of no the formal urban plan, it can be based on the requirements specified in the current TCVN 4054 standard and consider the current conditions, nature, flood frequency, and elevations controlled by construction works. underground works and above-ground works.

QCVN 07-2:2016

2.1.1. The external drainage system must conform to the approved urban drainage planning, urban planning, specialized planning on urban drainage approval and sustainability in the context of climate change.

QCVN 07-4:2016

2.7.2. The design elevation of the street should follow the levels in the construction planning, urban planning to ensure convenient traffic and drainage of the adjacent residential areas.

2.7.4. It is necessary to investigate for determining the maximum flood level and flooding time in storm season, for defining the highest underground water levels for cutting and embankment performance and to forecast calculated moisture content (critical moisture content) within loading impact distance, and for selecting the design option to limit impacts of moisture sources and quick drain from pavement.

QCXDVN 01:2008

3.1.4. Requirement of the technical issues

- It needs flooding protection for the urban areas which are along river or sea bank.
- Minimum elevation of the structure foundation should be 0.3 m higher than calculated flood level for civil land and 0.5 m for industrial land relatively.
- Elevation of dykes should be consistent with the irrigation planning

The calculated flood level is the maximum water level occurred in the period (or flood frequency) as in Table 3.1

TABLE 3.1: **Calculated flood level – maximum water level occurred in the frequency (period of years)**

Urban grade Functional areas	Special	Grade I	Grade II	Grade III	Grade IV	Grade V
Central area	100	100	50	40	20	10
Industrial park, warehouse	100	100	50	40	20	10
Residential area	100	100	50	40	20	10
Green area, sport area	20	10	10	10	10	2
Rural residential area	Civil structures > H maxTBnăm Public structures > H max + 0,3m					

3.4.2 Rainwater drainage planning

- Must be compatible with the irrigation system.
- For rivers and streams flowing through residential areas, it is necessary for stabilization and protection river/stream slope for land sliding resistance.
- Drainage system should be designed in the appropriate method.
- For residential areas located on hillsides and on mountains slope, it is necessary for designing the drains to collect waters from hill and mountain slope to protect the residential areas from water flows
- It is necessary to provide solutions to prevent and reduce damage caused by floods.

Although there is not any conflict between the road design standards on the frequency of rain and floods for the calculation of the work design, the designers still are challenged during design to ensure flood protection. In order to calculate the design to ensure flood limitation for the works, the standard TCVN 4054: 2005 stipulates the frequency of hydrological calculation of the works on the motorway, depending on the type of work and the road class. (Table 1). From the specified frequency, hydrological calculations of the flow and hydraulic calculations of the works are performed to determine the design elevation of the works: roadbeds at riverside sections, at the location of small bridges and culverts. The road elevation along the river and the flooded area must be at least 0.5m higher than the overflow water level based on the designed flood frequency and consider the height of waves hitting on road slope. The bridge elevation is calculated by the overflow water level corresponds the designed flood frequency, plus clearance and bridge grid height. The allowable height of flooded water on the spillway depends on overflow velocity on the spillway surface and designed vehicle. When designing a large bridge, if the invested historical flood level higher than the designed water level, the historical flood level must be used as the basis for calculating drainage structure size and capacity. The design standards are applied similarly to regions without referencing flood protection standards for river basin or urban areas.

TCVN 4054:2005 stipulates for the designed flood frequency should be considered from an economic, technical and environmental point of view in critical cases, as stated in the standard: "the design consultant is responsible for proposing and checking the long-term stability of the works and providing decision is under the authority of the person competent to decide on the investment". A general requirement without specific guidance can make designer difficult to recommend the frequency of flooding for designed structures. In addition, giving responsibility of long-term stability check to the designer seems inappropriate.

While TCVN 4054:2005 states: "at the road sections crossing cities or residential areas, the designed road elevation is specified following fixed-elevation in urban planning and the flood frequency to calculate the drainage works and roadbeds according to urban design standards", there are not specific provisions in TCXDVN 104:2007 for the designed flood frequency, except the article in Table 1. It is clear that it is difficult to find a connection between the provisions of flood prevention standards.

Apart from regulations for standard design implementation, Vietnamese design consultants are not provided with legal support for data collection as well as design guidelines. Standard [29] (Article 5.2.1) prescribes the calculation of the peak flood discharge corresponding to the design frequency with the maximum daily rainfall parameter corresponding to the design frequency of the representative hydro-meteorological station to the time calculation point. This standard or any other road design standard deals with regulations as well as the legal order and procedures for hydrometeorological stations to issue rainfall data series. There is also no documentation to process the series of rainfall data from different stations with different raw data characteristics, to get the maximum rainfall corresponding to the design frequency.

The design standards of Vietnam provide regulations for design work, with regulations that are either general, or sometimes have specific provisions for some cases. Design standards are therefore in the form of a semi-standard (with regulations on design principles), a semi-guideline (with specific provisions for cases), but not universally enough for all cases. , cannot be effectively supported as a design guide. A general regulation such as Article 7.8.7 TCVN 4054: 2005 [25] "The slope of the embankment must be reinforced by measures suitable to local hydrological and climatic conditions to prevent erosion caused by the impact of precipitation, currents, waves and changes in inundation" is not a design guide. The design guide in this case should provide reinforcement design solutions, selection or calculation guidance for solution selection. But if such design guidance were to be included in the standard, there would be limitations to its application. The standard is highly legal, the updating process is complicated, in case there is a technical solution or new technology, there is not enough legal basis to apply until the standard is updated.

Standards are highly legal, that is, hard rules cannot be broken, while guidelines can be flexibly applied to specific provisions included in the standard. Specific provisions that lack universality when included in standards can also lead to errors. For example, the specific value of horizontal slope in both standards [23] and [24] is only specified depending on the type of road surface material to ensure surface water drainage, regardless of the width. roads, not integrated with longitudinal slopes and ramp lengths, i.e. standard designs capable of generating potentially long stretches of road with surface water flowing in oblique and/or longitudinal directions cause surface erosion.

The general traffic infrastructure design standards in Vietnam are not reviewed and updated to keep up with changes in policy, institutions and natural conditions, or if revised, in the same way. not suitable. TCVN 4054:2005 has been used for more than 13 years without consideration for updating, despite the newly issued Road Traffic Law (in 2008), the Road Signing Regulations (QCVN 41:2012). and QCVN 41:2016); Standard for calculation of flood flow characteristics TCVN 9845: 2013 [29], updated from standard 22TCN 220-95 [30], that is, after 18 years, the 2013 version has also been 5 years old and has not had any regulations related to climate change and sea level rise.

Calculation of flood flow characteristics according to standard TCVN 9845:2013, which is a revised standard from 22TCN 220:95 with many significant positive changes:

- There are instructions for calculating and determining the design flood peak discharge according to the limiting intensity formula: according to the calculation order, clearly with the cases with hydrological stations and without hydrological stations, with tables of numbers. Supporting data, especially the rain curve coordinate table of the shower zones of Vietnam are available.

- Including the calculation of the construction aperture taking into account the water storage in front of the work, with instructions for calculating the total design flood volume, instructions for constructing the flood path, and calculating the time to flood the precious crop area.

- Detailed requirements for the calculation steps, not only at determining the construction aperture and the height of the water rise in front of the building as before, dotted the water level as the basis for the longitudinal profile design, but also required assessment of the time of flooding in precious crops, checking the possibility of overflowing in the lowlands and the demarcation points of the longitudinal profile, measures to strengthen the flow at the outlet and entrance to the work.

- Requires calculation of design flood peak discharge according to continuous rain data up to the time of design and a list of meteorological stations nationwide.

Although the standard is very innovative and has improved fundamentally, it is not yet synchronized, from the collection of data from the meteorological station (forms, data), to the processing to get the calculation parameters (here is the amount of data collected from the meteorological station). maximum daily rainfall corresponding to the design flood frequency; or there is a (legal) obligation to provide this parameter directly (for free) to meteorological stations and the procedure for providing it. , although it has added computational support with more detailed steps, it is still difficult for designers, especially at the local level, to implement.

Infrastructure works such as roads, reservoirs, canals, or residential areas, industrial parks, etc., after being designed and built, will change the mechanism of flood transmission and distribution in the basin, as a road crossing over the flood route especially in case it is not provided with adequate drainage facilities. A powerful design calculation tool that considers the mutual influence between the basin topography, capable of updating information on the integrated infrastructure system will result in flood protection and natural disaster response design calculations. good ear, effectively supporting the goal of better rebuilding of reconstruction programs. The results from a case study using hydro-morphological analysis tools of the GIS integrated area [33] show that: A road construction blocks a flood outlet, the elevation of this road project changes. change, increase or decrease by 1.0 m, changing flood distribution and floodplain; changing the longitudinal profile of the road works not only changes the position of flooded sections on the main road, but also changes the flood distribution line and flood position in the area; Inundation levels in different areas are influenced by location and route elevation, and change over time depending on rainfall intensity and duration. With this tool, one can analyze the risks to people and vehicles during flooding and the solution can be controlled by analyzing the area morphology and hydro-meteorological data.

The impacts of climate change have been distorting the rainfall regime and flow patterns in the region, the number and intensity of tropical storms are especially increased and irregular, causing hydrological changes in the flows. Central region becomes more complicated. Meanwhile, at present, Vietnam does not have a specific and legal supporting technical tool in calculating the anti-flood design. Moreover, there is still a lack of necessary updates to standards or guidelines in planning, design, management and operation of transport and irrigation infrastructure works.

For the current set of bridge design standards TCVN 11823:2017 including 12 component standards, through reviewing and reviewing component standards, the expert team found that the above set of standards inherits the standard 22 TCN 272 -05, update the revised versions of ASSHTO.

From a review, there are more than 50 articles referring to factors related to climate change distributed in 12 component within the set of bridge design standards. Issues related to the influence of environmental conditions during the design process such as; parameters of wind, temperature, precipitation. and also consider problems of flood, erosion, drainage, displacement deformation of the structure or structural parts due to displacement. The requirements for basic materials closely follow the requirements at the time of standard development and promulgation (from 2017 and earlier).

The reference standards have not been updated for issues such as (1) the navigable water level according to the riverway standard TCVN 5664 - 2009; (2) Parameters of temperature extremes; (3) Calculation of rainfall and drainage; (4) Wind zoning (5) Climate extremes affected by climate change.

Regarding the roadmap to consider and adjust design standards to adapt to climate change: the recommendation is:

- In the future, there should be studies to update ASSHTO standards on bridge design;
- Supplementary studies on building factors affected by climate change to bridge design such as coordinating with relevant ministries to develop maps on wind distribution, rainfall distribution, and temperature distribution;
- Develop maps of areas at risk of flooding, areas at risk of landslides and flash floods that can directly affect the design of bridge works.

WORKING PAPER 3 STRATEGIES FOR ADAPTATION TO CC AND LESSONS TO STRENGTHEN THE DOMESTIC SYSTEM

Author: Dr. Jasper R Cook, Tran Thi Kim Dang, Bui Ngoc Hung, Ly Hai Bang, Tran Viet Hung, Nguyen Kim Thanh, Bui Van Dai

Some suggestions:

- Plan for carrying out a survey of vulnerable assets;
- Assess the risk arising from climate change;
- Adjust guidelines for planning and design of adaptation measures and for risk assessment;
- Develop strategies for improving the knowledge base: promoting research, adapting results from climate research for practical application;
- Economic aspects: estimate the costs and benefits of actions (compared to the costs of no action) and relating the investments to risk level;
- Develop strategies for improving communication to road users, both before and after weather related events;
- Ensure a clear and well-communicated role for the National Road Administrations (NRAs) in securing a functional transport system. This could imply formulating strategy for the NRAs on a regional basis; (
- Develop strategies for implementation: formulating action plans, encouraging political effort /legislation.

TABLE 3.1. **Strategy Details**

Principle climate change risks	Implications for infrastructure	Remedial measures
Drought and effect of high temperatures	Affect the durability of road pavements by softening bitumen mixtures, leading to more rutting.	Stiffer binders could be recommended in some regions.
Flooding and erosion from increased precipitation and/or storm events.	Risk to embankments leading to unevenness in the road surfaces.	Considering run-off and necessary drainage capacity by the use of more conservative return periods (for coping with the lack of data on precipitation, runoff), or increasing the design capacity by an additional climate factor. Future design criteria should also focus on more robust foundation types, requirements for foundation depth, and erosion control. Have a frequent maintenance procedure along with risk and susceptibility analyses covering bridges, culverts, and other drainage structures.

Principle climate change risks	Implications for infrastructure	Remedial measures
Scour of bridges due to increase precipitation.	The shrink in expansion joints from some road bridges leading to bridge damage from temperature increases.	Retention ponds and sedimentation basins are a good protective measure if of adequate dimensions and functionally sited. A holistic approach to drainage design is needed, involving all water management parties as early in the planning process as possible.
Sea level rise	Coastal erosion, flooding, and wave splash-over, which may result in damage and traffic disruptions. Road embankments and bridge foundations may be exposed to more strain and erosion.	In short term, building higher dykes. A long-term solution requires the involvement of river valley management further inland. Developed a web-based tool that provides assistance in land-use planning for coastal areas with respect to the projected sea-level rise in the future.
Moisture fluctuation in road embankments from wetter winters and drier summers.	Bridge failures could lead to significant disruption to services and the need for emergency personnel	Improved drainage, appropriate alignment levels above flood levels.
Wind speeds and frequencies	Wind is also a key risk on roadside trees/vegetation, blocking roads and can be dangerous for high sided vehicles, especially on high roads and bridges.	Improved emergency plans. Revised designs

Utilize available climate change data effectively while taking into account local uncertainties: it is a vitally important step in undertaking scientific analysis of climate data for a better planning decisions due to the difference between local climate characteristics (different between regions).

Evaluate vulnerabilities and identify vulnerable groups, sectors, sites: in the road network planning, it is the sectors, infrastructure services, housing or materials that would be at high risk by climate impacts.

Engage multiple stakeholders: in any plan, it is valuable and necessary to have the involvement of a broad range of stakeholders from local sector interests (local people), government and scientists. In road network planning, while specialized scientific knowledge is needed to interpret climate data, future projections and impact estimates. This kind of assessment requires diverse expertise including local knowledge (for example, behaviour of local streams under flood conditions). Government plans need to also take account of autonomous adaptation measures undertaken by local residents and private sector businesses, which can best be understood through their engagement in the planning process.

Carry out the risk assessments which considers both the likelihood of a future event and the losses, damages, vulnerability.

Local government staff lead and coordinate planning, monitoring and implementation: to build their capacity in understanding and managing issues as well as their commitment to implementing proposed measures.

Design and construction

Drainage and culverts: Design standards should be adapted to the demands of climate change. Maintenance of existing drainage structures should be carried out with respect to future needs, and if possible as a part of planned regular replacement of old systems.

Bridge design: should have good erosion protection and robust foundations in considering design levels for flood.

Landslide protection: develop the prediction models and risk assessment methods to prevent landslide at optimization level. Furthermore, design guidelines for landslide protection should be adapted to changed conditions wherever necessary, and the risk of new landslide types (such as debris flow and slush avalanches) assessed. Models for identifying priorities should be developed and adapted to climate change.

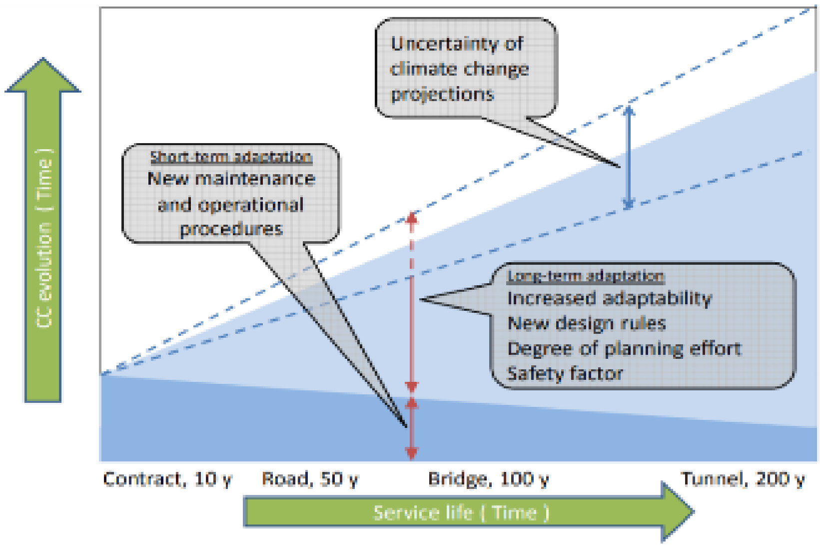
Road structure and pavements: stiffer binders (but environmentally safe) to protect against increasing temperatures; asphalt design that is resilient to saline intrusion; hydrophobic pavements that reduce slipperiness in areas where the temperature is around 0°C, nights are cold, and days warm, e.g. in mountain areas; and hydrophobic structure treatment, which can keep the water away from the structure.

Environment protection: (i) The design and placement of sedimentation basins should be undertaken in such a way that they can also be used for the retention of flood water. (ii) The road should be recognized as a barrier for waterways, but also for wildlife. Ensuring corridors for wildlife in new conditions in a future climate is an important part of the design. (iii) Due to better conditions for vegetation growth, maintenance of vegetation may require more attention. The aim is to ensure good visibility. Maintenance problems can be reduced by adequate planning.

Some principles when making decisions concerning adaptation measures:

It is the most important to take into account the uncertainty of climate parameters and also climate projections. These considerations will help in deciding what should be done first, what can wait, and what should wait: The design life of a new structure (or the remaining design life of an existing structure being assessed) must be seen in relation to the time aspect of climate change. It is not necessary to take into account climate aspects that will not be fully developed during the service life of a structure. The time aspect should always be seen in relation to the projected development in the most detrimental climate parameter: e.g. precipitation intensity for drainage capacity, sea level rise for planning of sub-sea tunnels

FIGURE 3.1. **Service life, climate change evolution, and short-term and long-term adaptation measures for maintaining the acceptable risk level**



WORKING PAPER 4 VIETNAM-JAPAN SATREPS PROJECT "DEVELOPMENT OF LANDSLIDE RISK ASSESSMENT TECHNOLOGY ALONG TRANSPORT ARTERIES IN VIETNAM" AND ITS IMPACT TO THE VIETNAMESE SOCIETY

Author Dinh Van Tien, Nguyen Kim Thanh

An ODA Project "Development of landslide risk along transport arteries in Vietnam (ICA/JST-ITST, 2011-2016)" has been taken as the basis for this paper..

The short-term project objective is landslide risk assessment technology to reduce on transport arteries developed by joint research based on experimental technology from Japan. The long-term objectives is embedment of development of landslide risk assessment technology and early warning systems for transport arteries and mountainous resident areas in Vietnam.

The contents of project include (1) Development of Landslide Risk Assessment Technology and Education; (2) Wide-area Landslide Mapping and Landslide Risk Identification; (3) Soil Testing – Computer Simulation of Landslide Initiation and Motion and (4) Landslide Monitoring and Development of Early Warning System.

The following summarizes the research outputs relevant to discussion on climate change impact:

Development of Landslide Risk Assessment Technology and Education

Based on the technological transfer from Japan to Vietnam, Vietnamese researchers have drafted integrated guidelines for landslide risk assessment in the 5 parts with 33 guidelines (GL), which cover on (1) Mapping and Site Prediction, (2) Material Tests,(3) Monitoring,(4) Landslide flume experiment and (5) Software application. Those guidelines will be first step for strategy of national standard development for landslide risk assessment in Vietnam. (Sassa, Project report 2016). When they will be the national standard, they will contribute to national strategy for natural disaster prevention, response and mitigation.

Mapping group has investigated slopes along Ho Chi Minh Route (HCM) between Khan Duc to Prau and the Hai Van pass land mass area. During the investigation landslide position, type of movement, micro features, causative factors were recorded as basic data. National No.7 highway was the additional target for application of landslide inventory by air-photo interpretation landslide investigation data and discussion, a landslide type classification in consideration of fuzzy nature and geological mechanisms of landslide generation in center of Vietnam were studied and published.

Wide-area Landslide Mapping and Landslide Risk Identification

After 5 years the work group has established six sheets of landslide inventory map and risk assessment map for HCM and 60 km long detail scale landslide distribution map (scale 1:12000);

A landslide inventory map for Hai Van area for designation of landslide monitoring site; a landslide susceptibility for road corridors a long HCM route (Dak Rong to Kham Duc section, scale 1: 250.000).

In addition, a LS inventory map for around 10 km along National No.7 highway (Muong Xen to Tam Quang section) was established as Vietnamese application with advice from Japanese experts. The combination of the landslide risk assessment map and the landslide susceptibility map will be made an effective tool for prevention and mitigation of landslide

Soil Testing – Computer Simulation of Landslide Initiation and Motion

A testing group developed a high-stress undrained dynamic loading ring shear apparatus (ICL-2) which can be applied to deep landslides (more than 100m deep). The methodology and testing from this apparatus is useful for understanding the deep-seated landslide moving mechanism. The developed ring shear apparatus was revised in 2014-2015 based on the experiences of testing by Vietnamese short-term and long-term trainees. The revised apparatus was installed in ITST in June 2015 and now it is available for testing. (Lam.H.Q, project report 2016)

Adding the function simulating tsunami generated by landslides as one of target of JST research was completed to integrate the tsunami simulation code developed by the Intergovernmental Oceanographic Commission (IOC) and the landslide simulation code (LS-RAPID). This function was applied to assess tsunami level possibly triggered by a large-scale rapid landslide from the Hai Van slope. However, Hai Van case is just the first experiment for risk forecast and evaluation.

The application of ICL-2 apparatus and LS-RAPID will be very powerful tool for buildup landslide hazard map. And it will directly contribute for Vietnamese's Government strategy of Developing science and technologies related to natural disaster prevention, response and mitigation

Landslide Monitoring and Development of Early Warning System

Hai Van landslide was selected as target area for monitoring and early warning. The installation equipment for monitoring, topographic and geology survey had been done. Rainfall and slope deformation monitoring of Hai Van slope was started in May 2013 and number of slope deformation records during heavy rainfalls have been monitored from September 2013 to now. An Installation of the data transferring and displaying system was finished in Hai Van and the project office in ITST, Hanoi in March 2016. This monitoring system could be able to allow monitoring real-time. The Hai Van landslide monitoring site is the modernist and biggest monitoring site in Vietnam up to now and it should be maintained not only for its functions but also remained as site training for Vietnamese researchers as well as the community.

The achievement of The Technical assistance Project "Development of Landslide Risk Assessment Technology along Transport Arteries of Vietnam" is evaluated as successful. It contributes directly for natural disaster prevention including climate change impact, response and mitigation of Government Strategy under effort to "proactively prevent natural disasters".

On socio-economic side, the landslide risk assessment technology, including zoning of areas at landslide risk, monitoring of sliding block movement and simulation of the landslide formation and development, is a key platform in the landslide risk assessment and management system. This technology is the basis for the system to predict the risk level, decide whether or not and make the reasonable control measures to minimize for the unacceptable risk level.

The evaluation which supplied by the system will help the management to have full awareness on landslide risks of and make appropriate decisions, including budget distribution planning for landslide treatment before the disaster actually occurred, thus it contribute to reducing the loss of human, economic and other negative impacts on society caused by landslides.

Besides the above scientific and socio-economic significant, the development of landslide risk assessment technology, including early warning system also have great meaning for communities in large landslides risk areas. Early warning system will help people know about the risk and protect themselves before the risk occurs.

After the end of the project, the Ministry of Transport assigned ITST to continue developing 33 Guideline from the project into basic standards and gradually select some standards to upgrade to Vietnamese standard

WORKING PAPER 5 - POLICIES AND PLANS

Author: Dr. Jasper R Cook, Tran Thi Kim Dang, Bui Ngoc Hung, Ly Hai Bang, Tran Viet Hung, Nguyen Kim Thanh, Bui Van Dai

1. National policies and programs to respond to climate change

Vietnam has issued a number of policies related to climate change response. Some of the promulgated laws have initially provided for climate change response such as Laws on Water Resources (2012), Natural Disaster Prevention and Control (2013), Environmental Protection (2020), Hydrometeorology (2015) , Forestry (2017).

According to statistics (from the report of the Ministry of Natural Resources and Environment (2020): Technical Report on the Nationally Determined Contribution of Vietnam). Up to now, the policies and documents under the Law have been approved by the Government and ministries. More than 300 important documents have been issued, including 19 documents of the Government and over 60 documents of the Prime Minister directly or indirectly related to climate change.

Up to 2019, the number of policy actions on climate change adaptation that have been developed is 115 policy actions. One of the important bases for the development of policies and laws on climate change adaptation is the Climate Change and Sea level rise scenario for Vietnam, updated in 2016.

Synthesize a list of Decrees, circulars, standards, guidelines, etc. related to road traffic planning with a sustainable orientation with climate conditions and/or considering climate change conditions

- Decree No. 37/2019/ND-CP dated May 7, 2019 of the Government detailing a number of articles of the Planning Law
- Decree No. 66/2014/ND-CP dated July 14, 2014 detailing and guiding the implementation of a number of articles of the Law on Natural Disaster Prevention and Control
- Directive No. 30/CT-TTg dated July 27, 2020 of the Prime Minister on Tasks, solutions, and implementation of concurrent formulation of master plans for the period 2021-2030, with a vision to 2050
- Directive No. 13/CT-TTg dated May 20, 2019 of the Prime Minister on Sustainable Development
- Resolution No. 120-NQ/CP dated November 17, 2017 of the Government on sustainable development of the Mekong Delta to adapt to climate change
- Decision 1719/QD-TTg dated October 4, 2011 of the Prime Minister approving the criteria for evaluating priority projects under the Support Program to Respond to Climate Change (SP-RCC)
- Decision No. 355/QD-TTg dated February 25, 2013 of the Prime Minister approving the adjustment of the development strategy of Vietnam's transport to 2020, with a vision to 2030.

- Decision No. 1570/QD-TTg dated September 6, 2013 of the Prime Minister approving the Strategy for exploitation and sustainable use of natural resources and protection of the marine environment until 2020, with a vision to 2030.
- Decision No. 681/QD-TTg dated June 4, 2019 of the Prime Minister on promulgating a roadmap for the implementation of Vietnam's sustainable development goals up to 2030.
- Decision No. 274/QD-TTg dated February 18, 2020 of the Prime Minister approving the task of making environmental protection planning for the period of 2021 - 2030, with a vision to 2050.
- Decision No. 1055/QD-TTg dated July 20, 2020 of the Prime Minister on promulgating the National Plan to adapt to climate change for the period 2021-2030, with a vision to 2050
- Decision No. 1980/QD-TTg dated October 17, 2016 of the Prime Minister on the national set of criteria for new rural communes for the period 2016-2020
- Decision No. 995/QD-TTg dated August 9, 2018 of the Prime Minister on assigning tasks to ministries to organize the formulation of national sector planning for the period 2021 - 2030, with a vision to 2050. Road network planning is one of five specialized master plans organized by the Ministry of Transport.
- Decision No. 2053/QD-TTg dated November 23, 2015 of the Prime Minister approving adjustments to the master plan on transportation development in the northern key economic region to 2020 and orientation to 2030.
- Decision No. 2054/QD-TTg dated November 23, 2015 of the Prime Minister approving adjustments to the master plan on transportation development in the central key economic region to 2020 and orientation to 2030.
- Decision No. 2055/QD-TTg dated November 23, 2015 of the Prime Minister approving the adjustment of the master plan on transportation development in the southern key economic region to 2020 and orientation to 2030.
- Decision No. 45/QD-Ttg dated January 10, 2020 of the Prime Minister on Environmental Protection is specified in the decision approving the task of making the National Road Network Master Plan for the period of 2021-2030 and vision to 2050.
- Decision No. 438/QD-TTg dated March 25, 2021 approving the Project "Development of Vietnamese Cities to respond to Climate Change in the 2021-2030 period".

Review the National Plan to adapt to climate change for the period 2021-2030, with a vision to 2050 and road map for transport sector

The Prime Minister issued Decision No. 1055/QD-TTg on Promulgating National Climate Change Adaptation Plan for 2021 - 2030 period with a vision by 2050.

The Promulgating National Climate Change Adaptation Plan aims to reduce vulnerability and risk to the impacts of climate change through strengthening resilience, adaptive capacity of communities, economic components and ecosystems; promote the integration of climate change adaptation into the strategic and planning system.

2. Tasks and solutions

Accordingly, in the period 2021 - 2030, with a vision to 2050, the Plan identifies 3 groups of tasks and specific solutions to address the above-mentioned goals, including:

1. Improve the effectiveness of climate change adaptation through intensifying the state management of climate change, including climate change adaptation contents, and promoting the integration of climate change adaptation contents into relevant strategies and planning

The climate change adaptation has been implemented under the framework of the national strategy for climate change, the national action plan for response to climate change, action plans of ministries, central agencies and local governments, climate change response target programs, schemes/ projects of ministries, central agencies, regional and local governments, and international cooperation projects.

Intensifying the state management of climate change, revising climate change-related policies, strategies and planning, and promoting the integration of climate change adaptation contents into relevant strategies and planning are necessary to improve the effectiveness of climate change adaptation. Specific tasks and solutions:

a) Develop and revise the national legal framework for climate change. Perform activities and duties to serve the formulation of the Law on climate change based on full compliance with regulations of the Law on promulgation of legislative documents.

b) Review, update and formulate new socioeconomic development planning and sectoral development planning based on climate change scenarios and assessment of climate change impacts, especially those on industrial sectors/regions that are particularly vulnerable to the adverse effects of climate change.

c) Promote the integration of climate change adaptation into relevant strategies and planning through formulating and promulgating guidelines for such integration; assess the integration of climate change adaptation into relevant strategies and planning; combine climate change adaptation and disaster risk reduction.

d) Carry out observation and assessment in order to enhance the effectiveness of climate change adaptation, including the promulgation of criteria for assessment of climate risks, determination of climate change response projects/tasks, and assessment of effectiveness of climate change adaptation actions. On such grounds, a system for observation and assessment of climate change adaptation actions will be developed and operated.

e) Promote adaptation actions which will bring co-benefits for disaster management, reduction of the risks of climate change and social, economic and environmental efficiency; periodically update climate change scenarios according to reports of the Intergovernmental Panel on Climate Change (IPCC); establish and operate the national climate change database and support tools for management and forming of climate change policies; develop mechanisms/ policies, and mobilize and allocate financial resources, for encouraging and attracting investments in climate change adaptation actions.

g) Intensify international cooperation and fulfill duties of a signatory of UNFCCC, including: provide support for domestic authorities for capacity-building in order to be recognized by the Green Climate Fund, the Adaptation Fund and other funds; prepare and periodically update the National report on climate change adaptation to the UNFCCC. Monitor and assess the impacts of climate change adaptation actions on the world on Vietnam, and determine solutions for minimizing any adverse impacts and taking advantage of such impacts to achieve socioeconomic development objectives.

2. Improve the resilience and adaptation capacity of communities, economic sectors and ecosystems through making investments in adaptation actions, science and technology, and increasing public awareness to be ready to adapt to climate change

This group of tasks can be fulfilled through improving natural systems and infrastructure facilities of industrial sectors/fields, and investing in, performing and enlarging adaptation actions and models. Investment projects on construction and improvement of natural systems and infrastructure facilities must ensure a systematic, interdisciplinary, inter-regional approach with key contents and reasonable roadmap. Continue to communicate and step up activities for increasing the public awareness of climate change adaptation. Specific tasks and solutions:

a) Improve infrastructure facilities for strengthening capacity of industrial sectors/fields to adapt to climate change:

- Effectively manage water resources; supervise and protect water resources; improve the water storage capacity and effective use of water under climate change conditions, especially in regions threatened by droughts or water scarcity or adversely affected by saltwater intrusion;

- Develop and scale up intercropping models which are suitable for drought or saltwater intrusion conditions, and cultivation and animal breeding models which are adaptable to climate change. Perform climate change adaptation actions in agricultural sector; enhance effectiveness of use of agricultural land; arrange crop structure and types of plants that are suitable for the comparative advantage and market in each region; prevent and control diseases and pests for plants and animals (including aquatic animals); develop and scale up plant varieties and animal breeds; intensify highly effective fishing and aquaculture methods; improve methods, techniques and infrastructure facilities in aquaculture sector;

- Upgrade and improve traffic facilities in regions with high disaster risks and particularly vulnerable to climate change;

- Improve resilience of urban infrastructure systems and concentrated residential areas, industrial parks and resettlement areas in coastal areas and islands; adopt measures for protecting urban areas from floods caused by climate change and sea level rise; develop and build houses that can withstand disasters, extreme climate events and sea level rise; apply new and advanced building technology and materials that are adaptable to climate change to construction and urban management;

- Upgrade and improve infrastructure facilities for industrial, energy and commercial sectors, and industrial establishments, and concurrently adopt measures for environmental protection and reasonable and efficient use and extraction of natural resources in regions that are particularly vulnerable to climate change;

- Develop the medical and healthcare network that is capable of preventing and controlling epidemics, diseases and other diseases emerged from climate change, and ensuring environmental sanitation conditions; adopt technological and equipment solutions in medically preventing and treating diseases increased due to climate change; strengthen the system for observation and early warning of climate change impacts on human health; build and scale up models for improving resilience of communities, climate change adaptation of health branch and public health;

- Maintain, preserve and upgrade infrastructure facilities and buildings of historical-cultural relics in order to improve their resilience to climate change.

b) Improve adaptive capacity of natural ecosystems and biodiversity to climate change impacts through intensifying the management of ecosystems and biodiversity; intensify the restoration of natural ecosystems and protection and conservation of biodiversity from the adverse impacts of climate change and sea level rise.

c) Develop and scale up ecosystem-based and community-based climate change adaptation models; intensify the participation of local communities in observation, conservation and management of biodiversity.

d) Manage forest protection and improve the quality of forests through forest regeneration, restoration and enrichment; intensify the participation of communities in development of planted forests in order to improve livelihoods and employment opportunities in forestry sector.

e) Increase awareness and knowledge about climate change and disasters of governments at all levels, social organizations and communities; improve capacity, empower women and promote gender equality in climate change adaptation.

f) Do scientific research and technological development, and focus on application of new and advanced technologies to climate change adaptation.

3. Reduce disaster risks and minimize damage in order to be ready to cope with disasters and extreme climate events increased due to climate change

Reducing disaster risks and minimizing damage in order to be ready to cope with disasters and extreme climate events increased due to climate change require simultaneous implementation of groups of solutions related to capacity-building for forecasting and early warning disasters and extreme climate or weather events, improvement of disaster risk management system for minimizing the vulnerability and enhancing the preparedness for coping with extreme climate events, and timely and effective implementation of adaptation solutions for minimizing damage associated with the short-term, medium-term and long-term impacts of climate change in the future. Specific tasks and solutions:

a) Prepare for cope with disasters caused by climate change through intensifying the capacity for observation of climate change, meteorological and hydrological monitoring, forecasting, warning and spread of news on disasters and extreme climate events.

b) Ensure the safety of hydraulic structures and disaster management structures in order to proactively cope with disasters which are increasing in both frequency and intensity.

c) Improve the disaster risk management system, carry out determination, zoning and forecasting of disaster risk levels; intensify capacity and measures for managing and promoting mitigation of disaster risks, especially community-based disaster risk management, and promotion of local knowledge in disaster preparedness for decreasing the vulnerability and increasing the preparedness for coping with extreme climate or weather events.

d) Minimize damage associated with the short-term, medium-term and long-term impacts of climate change through punctually and effectively implementing disaster management solutions, especially in regions which are most affected by storms, floods, inundation and landslide.

dd) Prevent river erosion and coastal erosion; cope with increased droughts and saltwater intrusion; deal with losses and damage caused by climate change impacts.

3. Implementation phasing

The implementation of the national climate change adaptation plan for the 2021 – 2030 period with a vision by 2050 is phased as follows:

2021 – 2025 phase

In the 2021 – 2025 phase: focus on revision and completion of climate change adaptation mechanisms and policies; prepare legal grounds and technical conditions for promoting the integration of climate change contents into relevant policies, strategies and planning; implement prioritized climate change adaptation tasks and solutions, improve capacity for coping with disasters and minimizing damage caused by disasters and unusual climate or weather changes. Key tasks and solutions in the 2021 – 2025 phase:

a) Establish and complete the national legal framework for climate change as the basis for formulation of the Law on climate change; review, update and formulate socioeconomic development planning and sectoral planning based on climate change scenarios; promote the integration of climate change contents into relevant strategies and planning; observe and assess the effectiveness of climate change adaptation.

b) Provide support for domestic authorities for capacity-building in order to be recognized by the Green Climate Fund, the Adaptation Fund and other funds; prepare and periodically update the National report on climate change adaptation to the UNFCCC.

c) Develop and scale up intercropping models adaptable to climate change; enhance the effectiveness of use of agricultural land; arrange appropriate crop structure and types of plants;

develop and scale up plant varieties, animal breeds, and cultivation and animal breeding models which are adaptable to climate change.

d) Manage ecosystems and biodiversity; intensify the restoration of natural ecosystems and protection and conservation of biodiversity; step up ecosystem-based and community-based climate change adaptation models.

dd) Carry out observation of climate change, meteorological and hydrological monitoring, forecasting, warning and provision of information on disasters; improve the safety of disaster management structures; punctually and effectively implement solutions for preparedness and control of disasters, including storms, floods, inundation and landslide; adopt measures for protecting cities and concentrated residential areas from floods; prevent and manage river erosion, coastal erosion, droughts and saltwater intrusion; improve resilience of infrastructure facilities; upgrade and improve traffic facilities in regions with high disaster risks and particularly vulnerable to climate change.

e) Strengthen human resources for climate change adaptation, including training programs/courses; do research on climate change adaptation; implement human resource development schemes; attract investments in climate change adaptation actions; intensify international cooperation.

2026 – 2030 phase

In the 2026 – 2030 phase, continue to intensify the state management of climate change, cooperation and combination of climate change activities with relevant tasks and solutions for improving capacity of industrial sectors/areas, economic sectors, communities and ecosystems in order to increase the resilience and preparedness for adapting to climate change. Continue to improve resilience of infrastructure facilities and adaptive capacity of natural ecosystems and biodiversity; intensify the restoration of natural ecosystems and protection and conservation of biodiversity from the adverse impacts of climate change. Promote adaptation actions which will bring co-benefits for reduction of the risks of climate change and social, economic and environmental efficiency. Monitor and assess the impacts of climate change adaptation actions on the world on Vietnam, and determine solutions for minimizing any adverse impacts and taking advantage of such impacts to achieve socioeconomic development objectives.

Vision by 2050

After 2030 to 2050, promote outcomes of the 2021 – 2030 period, continue to improve the capacity for adaptation to climate change of human, infrastructure facilities and natural systems in order to protect and improve the quality of life, and safeguard food security, energy security, water security, gender equality, social security, public health, protection of natural resources, national sustainable development in the climate change context and safety before disasters. Carry out the integration of climate change adaptation into all socioeconomic activities in order to gain initiative in climate change adaptation, take advantage of climate change impacts to achieve socioeconomic development objectives, and make positive contributions towards climate change response and protection of the earth's climate system to the international community.

Road map for transport sector is shown in Table 1 below

TABLE 5.1. **Road map for transport sector**

No.	Adaptation needs	Objectives	Tasks	Presiding authority	Expected outcomes in each period	
					By 2025	By 2030
1	Revise and complete policies, strategies and planning in transport sector	Review, formulate and complete strategies, planning, mechanisms and policies in transport sector for promoting the integration of climate change adaptation contents	Update and formulate strategies and planning according to climate change scenarios with paying special importance to sectors and areas vulnerable to adverse impacts of climate change	Ministry of Transport	2022: Strategies and planning are approved	
			Review, formulate and complete standards, technical regulations and technical instructions for construction of road, railway and waterway transport infrastructure adaptable to climate change	Ministry of Transport	2023: Standards, technical regulations and technical instructions are updated, completed and promulgated	
2	Improve resilience to climate change through measures for upgrading infrastructure in transport sector	Implement programs/ projects on upgrading and improvement of traffic structures in areas that are threatened by disasters and vulnerable to climate change	Upgrade, improve and construct road and waterway transport infrastructure in areas that are threatened by flood, inundation, sea level rise, especially Mekong Delta	Ministry of Transport, provincial People's Committees	2021: the scheme is approved; 2022-2025: the scheme is piloted in regions	Increase scale, make review and assessment
			Upgrade, improve and construct road traffic works that can withstand landslides in the northern highlands and the central highlands of Vietnam	Ministry of Transport, provincial People's Committees	2021: the scheme is approved; 2022-2025: the scheme is piloted in regions	Increase scale, make review and assessment

WORKING PAPER 6 - ADAPTATION BY SPATIAL AND TRANSPORT PLANNING

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1. Adaptation Strategies of the European countries

Framework of the European Union: Generally, extreme events resulting from climate change are regarded as a political challenge for the entire world. Thus the European Union understood the task of adaptation as a common challenge for all member states. The approval of NAS has happened in different years. Finland started in 2005, Spain and France followed in 2006, Norway in 2007, Germany, Denmark, the Netherlands and UK in 2008, Sweden in 2009, and Portugal in 2010. The most advanced National Adaptation Strategy (NAS) has been issued by the Netherlands, which are challenged by extreme weather events for a long time. First of all, adaptation strategies are the basis for developing risk maps to localize the dangerous areas. This is an essential tool for informing the public.

Middle Europe: For middle Europe, intensification and accumulation of extreme weather events such as heat, droughts, and floods are expected both from the sea and rivers. A distinct change of dry and wet periods contributes to subsidence of the ground, which causes damages to infrastructures.

Germany has adopted a comprehensive strategy and researches various projects with a focus on climate consciousness spatial planning. In terms of spatial planning, the German adaptation strategy highlights the meaning of planning instruments.

The Netherlands represents a particular case due to its topographic conditions; many lands lie under sea level. Thus, the national adaptation strategy has been drafted along with the spatial issues. One key element is the reduction of vulnerability of transport infrastructure. After focusing on technical solutions in the past, such as building material, pumping systems etc.), the current strategy highlights planning instruments. Roads can be protected from flooding by providing enough space for rivers for retention (infiltration). Moreover, the designation of multifunctional space offers a temporary water reservoir for heavy rainfalls.

The risk of flooding is also given for the south and east parts of the United Kingdom. Together with the Netherlands, only the UK already planned and partly realized options for action in road infrastructure.

Also, Denmark, Ireland, and Belgium focus on measures to reduce the impact of floods if transport infrastructure is concerned.

Northern Europe: This area, comprising the countries Finland, Norway, Sweden, and Iceland, will most likely be affected by more rain falls, a general increase in the temperature, a reduction of the area covered by snow, and a decline in depth of frost. The main problems for road infrastructure are flooding and wash-away. The national adaptation strategies of Finland, Norway, and Sweden explicitly address spatial and transport planning. The suggested action focuses on the flood risk (i.e., coast protection), such as (i) Extension of drainage along roads, (ii) Enforcement and regular maintenance of dykes, bridges, infrastructure, (iii) Risk maps. The adaptation strategy requires new road network plans regarding the height of roads to tackle rising water tables and the risk of landslides.

Alpine Region: In the mountainous areas of Austria and Switzerland, the transport infrastructure is challenged a lot by extreme weather events. Roads have to be adapted to the retreat of glaciers, heavy rainfall, and the melting of permafrost soil. Especially in river valleys, floods can cause damages to the road infrastructure. Both countries are currently developing a national adaptation strategy.

Austria elaborates hithes NAS with the involvement of all stakeholders and analyzing international examples. Measures to avoid dangers are strongly recommended, for instance, by fostering the danger consciousness, information campaigns, issuing of risk maps, and strengthening of flood risk management. The Federal Environmental Agency has developed a database of adaptation measures in collaboration with the Ministry of Agriculture, Forestry, Environment and Water Management, and Climate- and Energy Fund.

The Swiss NAS deals with nine sectors, among others with land use, handling of natural hazards and water management. Spatially relevant for the latter field is creating new large and safe dam reservoirs and the retention areas along the rivers. As for natural hazards, special attention is needed towards landslides, storms, earth flows, and floods.

Southern Europe: In contrast to the other regions, the southern countries suffer Spain, Portugal, Italy, and especially Greece from water shortage, heatwaves, and drought periods. Therefore adaptation projects aim to reduce water consumption in the real estate sector. In case of water shortage, Spanish municipalities are advised to develop emergency plans (cf. Meister et al. 2009, Swart et al. 2009). The Spanish NAS priories the conservation of biodiversity and protection of water resources. Spatial Planning is implemented on a regional base, such as the strategic environmental assessment.

2. Land Use and Road network planning

Road network planning is one part of the spatially relevant discipline of transport planning, defined as - goal-oriented, systematic, foresighted, and informed the preparation of decisions, which aim to influence the traffic according to the goals. Generally, planning measures are the basis for reducing infrastructure vulnerability and ensuring the necessary adaptation measures towards extreme weather events.

The German Strategy for Adaptation to Climate Change was issued in 2008. It contains the objective to create effective habitat systems by linking living spaces within the superregional road network. In order to avoid the separation of natural systems, it is necessary to thoughtfully design the planning of urban areas and transport infrastructures such as roads. In terms of planning, an important measure is to secure the road alignments by preventive planning measures. In order to minimize the necessary urban and regional roads, it is necessary to pursue a strategy of sustainable transport planning. This can be supported by a settlement structure that generates little traffic and enables bundling traffic together. To reach this goal, an integrated approach of town planning and road planning is necessary and has already been adopted at the regional level regarding several conurbations in Germany.

An example of this strategy can be seen in Hamburg, where the entire road infrastructure of a new urban development not protected by the main dyke is elevated on artificial foundations with a height of 7,5 to 8 m over mean sea level. A vital instrument within the German planning system is the Municipal land-use planning (Bauleitplanung), which enables municipalities to implement preventive measures, such as locate roads apart from endangered areas of flooding.

Finland: The National Strategy for Adaptation to Climate change in Finland also contains measures concerning road network planning. Besides infrastructure measures, the sector —land use and community planning—contains new norms and guidelines for road and railway planning and construction (Ministry of Agriculture and Forestry 2005, p. 220 et seq.). It is aimed to optimize all long-term plans in terms of traffic safety and warrant the functional capability of road infrastructure (Ministry of Agriculture and Forestry 2009).

Switzerland: Another exciting country to be reviewed here would be Switzerland due to its long-term practice in adaptation planning.

Canada: An exciting approach from Québec, Canada, to tackle the problem of fluctuations in sea levels, which also applies to European coastal areas, is the inclusion of the management of the road system within a long-term and integrated planning of the coastal zone.

3. Assessment of additional measures:

As the result of the review of the national adaptation strategies of the European countries, the following additional measures can be considered as most important:

Shifting of road alignments beyond areas at risk: The alignments of urban, regional, and national roads are decided after a specific procedure. Usually, this also includes a cost-benefit analysis; however, the standards are different among the countries. In order to guarantee the proper consideration of the danger of climate change and natural hazards, such as extreme weather events, a life cycle approach is necessary. Whereas it is relatively easy and quick to apply to new roads, it is difficult for already existing roads, which lie in vulnerable areas. Depending on the case (new planning or realignment), the costs will be very different. In the case of new planned roads, the measure can be relatively easily implemented. However, most (major) roads are already planned in Europe. Thus, the primary case will be the realignment of already existing roads, located in the area of risk. The costs are high because the shifting process requires an entirely new planning procedure. However, also the benefits are pretty high since the previous problems can be entirely avoided.

Road alignments with less land consumption and more effective utilization of existing infrastructure: In most cases, roads should be planned in an efficient thus economic way. However, considering possible damage due to weather extremes, the consumption criteria should be higher weighted. In order to keep the desired road capacity, ITS measures should be implemented, such as dynamic speed control and flexible lane direction designation. In the case of urban roads, also concepts of –shared space—should be considered. The benefit of this measure is stated to be moderate since investment costs can be lowered. However, the costs are meager, balancing the savings on construction costs with the investment in ITS.

Avoiding urbanization of areas at risk: This measure is already considered in the long term, especially for areas endangered by common natural hazards, such as floods, volcanoes, or avalanches. However, the strong economic interest of the landowners and developers and local political interest makes it very difficult to realize this measure for new urbanization. As for already existing developments, it is even more difficult to withdraw an already given building permission. If the implementation succeeds, the measure's benefits would be relatively high, and the direct cost would be virtually zero.

Concepts of removing the hard surfaces that are covering the ground/land rehabilitation program: To adapt to climate change and extreme weather events, also means to undertake measures within the urban structure. One major problem of the vulnerability of cities (and urban roads) to heavy rain and floods is the high level of sealing, i.e., surface covered by concrete and asphalt. Therefore areas that are not required anymore (such as seldom-used parking areas) should be revegetated, and the urban concept should include a sufficient amount of green areas such as parks and grass. However, there is often little leeway to remove the hard surface in highly densely urbanized areas. The benefits are high for the process of infiltration, but in case of heavy rain or flooding, this is often not enough, so that the benefit will be estimated as moderate. The costs are also moderate, depending on the extent to which the measure is locally implemented.

WORKING PAPER 7 - ADAPTATION BY ROAD INFRASTRUCTURE TECHNOLOGIES; A REVIEW OF SOME LITERATURE.

Authors: Dr. Jasper R Cook, Tran Thi Kim Dang, Bui Ngoc Hung

1. Prediction of future climate conditions with focus on roads

Since the possible adaptation of road infrastructure depends on future weather conditions, it is essential to improve predictions for climate change. Considerable uncertainty may consequently lead stakeholders to no action or reduce the cost-effectiveness of proposed measurements. For this reason, climatic models should be improved and downscaled. Generally speaking, precise predictions of climate conditions are the basis of adaptation strategy.

2. Use of new construction materials and new technology

Reducing the vulnerability of infrastructure can be achieved with new construction materials and new technology. The most important findings are presented below:

Development of new, heat-resistant paving materials

A more common use of polymer-modified bitumen, leads to improved mechanical properties of asphalt mixture, e.g., more resistance to rutting.

Improvement in pavement technology, for instance, compact asphalt ("hot on hot" technology), leads to better mechanical properties and durability of pavements.

Using polymeric grids to avoid rutting. - Some publications suggest that polymeric grids can reduce deformation during hot weather. According to [Dawson, 2010, Rep. Nr 11] it may not be cost-effective.

Using materials on the surface which reflect solar radiation and consequently reduce the temperature within the pavement. - Many authors, e.g. [Kayser 2009] propose using light-colored gravel.

Water-retention pavement, proposed by some authors, for example [Kawakami]. It can be challenging to implement in most European regions with hot summers due to the lack of precipitation in this season.

Polymeric and other non conventional aggregate treatments. An example is the soil treatment with Dry Powdered Polymers (DPP). Since DPP are costly, a cost-effective use may be limited to regions with exceptional conditions, e.g., high risk of flooding or with a high water table. [Carrera, 2010 a].

Rubber addition to asphalt. - Leads to the improvement of asphalt mixture properties, avoids rutting, and makes a possible reduction of the thickness of asphalt pavement. Furthermore, antioxidants in old tires used for modification of asphalt retard its aging. A positive side effect is the usage of old tires and, consequently, the reduction of the amount of waste. However, it should be considered that rubber can be harmful to the environment.

Ultra-thin, fiber-reinforced concrete overlays and special micro-surfacing. According to [Dawson, 2010, Rep. Nr 11], the negative effect of extreme heat can be reduced with this measure owing to an increase of stiffness of surface and more excellent reflection of solar radiation.

Using new additives for asphalt pavements. - An example can be anti-stripping additives, which can help avoid stripping due to a possible increase in precipitations.

Fiber reinforcement (fibers of diverse types, for example, glass fibres, added to cementitious stabilization). Some authors, e.g. [Carrera, 2010], indicate that these additives make materials stabilized by cementless brittle.

A more common use of porous asphalt. Very intensive rain may lead to aquaplaning and safety problems. It is well known that porous asphalt help to remove water from the road surface. Another positive effect is the reduction of noise compare to asphalt concrete. Furthermore, [Carrera, 2010 a] suggests that porous asphalt is more resistant to stripping. On the other hand, it is known that porous asphalt has a shorter service life.

Foam bitumen stabilization – proposed by [Carrera, 2010] for soil stabilization. Due to the authors, the addition of a small quantity of lime or cement has further advantages.

Materials with higher thermal conductivity. – [Kayser, 2010] proposed construction materials with higher thermal conductivity to reduce the temperature within asphalt pavement.

Geosynthetics, for instance, for reducing reflective cracking and rutting in pavements, for drainage, and for geotechnical reinforcement. Using of geosynthetics may also be needed to avoid erosion due to intensive precipitations. The main functions of geosynthetics are separation, filtration, reinforcement, and drainage.

Using drainage materials that can be easier inspected and maintained. – Many authors highlight that regular maintenance is a crucial measure to avoid flooding and guarantee the bearing capacity of roads. Predicted more frequent and more extreme precipitations can cause more frequent maintenance works after extreme events. To reduce the future expenditure and make quick repairs possible, designed drainage systems should be easy to maintain.

3. Design of pavements for future weather conditions, improvement of design standards and technology

Many experts from Europe and other continents underline that it may not be enough to maintain empirical design methods working well in the past. Changing technology, changing properties of construction materials, increasing traffic, higher permitted load on pavements, and changing environmental conditions need to be considered when designing pavements. Design methods based only on empirical data may not be sufficient to incorporate changing factors.

A solution for this problem can be mechanistic design methods. [Thodesen, 2010] states that mechanical-empirical design methods allow designers to evaluate different materials in different environmental as well as different traffic conditions and are, therefore, to be preferred. Also, other authors underline the importance of changing from the empirical methods to mechanistic-empirical, and finally, into mechanical methods. Since many roads in Europe have been still designed with old methods, much effort should be made to improve mechanistic methods and accelerate their design standards.

4. Design of pavement mixtures more resistible to future regional weather conditions

It is well known that the properties of asphalt mixtures depend on numerous factors. Through modification of bitumen, bitumen ration, grading curve, properties and shape of aggregates, or additives, it is possible to influence the properties of pavements mixtures and consequently the properties of pavements. To design appropriately pavement mixtures for future climate conditions and minimize effects of extreme events, it will be necessary to change the design process of asphalt mixtures.

5. Maintenance of pavements

Most authors highlight the importance of the maintenance of pavements. Due to restrictions in the budget, many roads are not maintained satisfactorily and are consequently more vulnerable to extreme events.

6. Design of road networks (reducing of vulnerability)

Many authors state that the vulnerability of road infrastructure can be reduced at the level of network planning, taking into account climate change. As an example, [Culp, 2009] proposes restrictions of development in floodplains, the return of some coastal areas to nature, and the relocation of some sections of roads. Moreover, he suggests that development in vulnerable regions can be influenced through higher flood insurance rates. However, this measure has substantial limitations in developed countries since probably the central part of the network at the end of this century will be comprised of currently existing infrastructure.

7. Adequate design and maintenance of bridges and tunnels

High temperatures lead to the thermal expansion of bridges. For this reason, possible higher temperatures should be taken into account when designing bridges. Joints should have the ability to accommodate predicted thermal expansion. Many authors suggest updating the design standards. Furthermore, due to probable higher maximal water flow in rivers caused by extreme precipitations, higher loads on bridges must be considered.

8. Improvement to the stability of slopes and embankments

Due to more intensive extreme precipitations or unfavorable changes in the condition of protective vegetation, landslides can occur more frequently. For this reason, additional works or changes in design standards may be needed to improve the stability of slopes.

9. Vegetation management along roads

According to hot spots, falling trees and wildfires will be causing severe problems as a consequence of more frequent and more intensive extreme events. The impact of droughts, causing wildfires and storms can be reduced with adequate vegetation management along roads and surrounding areas. Some vegetation species are less vulnerable to wildfires or can resist heavier storms. To avoid obstructions in traffic and safety problems in high wind speed, some trees in bad condition may need to be cut down.

10. Sealing of unpaved roads

[Dawson, 2010, Rep. Nr 11] reports that currently, unsealed roads in central Nordic regions may have to be stabilized. This would be very costly. A positive side effect is the reduction of dust. As environmental standards and expectations of road users are rising, probably many roads will be sealed independently of climate change until 2050.

11. Special measures in permafrost regions

Climate warming can cause severe problems in permafrost regions due to loss of soil stability.

12. Measures in response to the rising water table

Rising water table, caused, for instance, by sea-level rise, can cause problems to road infrastructure. To minimize the impact, it is recommended to elevate the infrastructure. However, it would be possible only for newly constructed roads.

13. Installation of monitoring systems combined with effective communication to users

It was established that traffic obstructions lead to severe economic consequences [Enei, 2011]. This can be minimized with the installation of monitoring systems. Nowadays, monitoring becomes more common not only because of weather extremes. It is very likely that in the following decades monitoring systems will be much more widespread and less expensive.

14. Taking into account other aspects of climate change and weather extremes

[Dawson, 2010] highlights possible indirect consequences of climate change. He concludes that aspects like transportation method, vehicle type, demographic change, or road users' expectations may significantly impact road construction and maintenance in the future.

15. Cooling of electronic infrastructure

The participants in the 3rd Workshop [Doll, Klug, 2011] suggested a need to improve cooling systems for electronic infrastructure on roads. Extreme heat may lead to a malfunction of telematic systems or traffic signals. Electronic equipment should be designed to be more resistant to heat.

16. Changes in operations

Due to changing environmental conditions, some changes in operations may be needed. Extreme events are likely to cause traffic obstructions and limitations. An example can be load limitations during extreme heat. However, road users' expectations and some trends, like the increasing importance of just-in-time supply, make such limitation unacceptable.

17. Cooperation between climatologists and road authorities

Since the early adjustment of road infrastructure is beneficent, different regional changes need other adaptation measures, and adaptation strategy should be adjusted to new results in climate projection; the cost-effectiveness of action can be improved through cooperation between climatologists and road authorities.

18. Tools to help decision-makers to invest right for adaptation measures

An example is the project "RIMAROCC - Risk Management for Roads in Changing Climate" [Adesiyun, 2011], which helps to estimate the risk of climate change.

19. Investment in research on properties and behavior of pavements

Nowadays, the exact deterioration processes of roads are still not fully understood. For this reason, it would be beneficial to improve the understanding of the behavior of pavements and, in this way, prepare the infrastructure to changing environmental conditions more adequately. This can be achieved with higher investment in research projects. This measure may be very beneficial even without climate change and can lead to more reasonable usage of natural resources.

20. Flood control

Floods will likely cause serious damage not only to the road infrastructure but also to predicted more intensive precipitations. Better flood control can be achieved, for instance, through the adjustment of protective walls and levees, retention areas, and regulation of rivers. It is essential to say that proper flood control is needed even in constant climate conditions.

21. Design of road drainage for future weather conditions

Many authors suggest higher dimensions of drainage systems as a response to changing precipitation characteristics. However, the trend in intensive rains of short life span (relevant to dimensioning of drainage system) is different from region to region, and often it is impossible to find significant explicit trends.

22. Maintenance management system for road drainage

Most authors underline the importance of proper and scheduled maintenance of road drainage. Results of the project "SWAMP – Storm Water Prevention, Methods to predict Damage from the Water Stream in and near Road Pavements in Lowland Areas" suggest that flooding can be prevented, mainly through the cleaning and maintenance of drainage.

WORKING PAPER 8 REVIEW AND LIST GUIDELINES, BEST PRACTICES AND EXPERIENCE NOTES WITH INTEGRATION OF CCR IN TRANSPORT PLANNING

Author: Ly Hai Bang

I. Documents reviewed

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1. Adaptation measures concerning climate change

Definition. It is first important to adopt the definition of adaptation to climate change because many scientific publications considering adaptation in transportation published since the early 1980s have just attempted to provide a definition the best suits the term. As defined by Parry et al. (2007), adaptation measures are *"initiatives and measures that can reduce the vulnerability of natural and human systems against actual or expected climate change effects"*.

Adaptation measures history. The International Panel on Climate Change (IPCC) only mentioned adaptation in its second assessment report in 1995, although the IPCC was first established in 1988. The necessity of adaptation strategies for climate change implications was recognized in the third assessment report (2001), which stated that because mitigation measures would not suffice to prevent climate change, adaptation measures and policies would be necessary (McCarthy et al., 2001).

Research on adaptation. Kaiser et al. (1993), and Rosenzweig and Parry (1994) reported that systems would adapt on their own to the ever-changing climate conditions. Smithers and Smit (1997) changed that perspective a few years later. They identified the various interpretations of adaptation thus far and proposed a classification scheme for differentiating adaptation strategies by recognizing the characteristics of climatic events and their properties.

Who or What. Smit et al. (1999) questioned who or what adapts. This question opened a new perspective in adaptation research, and it implied that adaptation measures could differ depending on the sector of human activity (transportation, energy, water, etc.). This difference is especially true for transportation, for which adaptation measures are vastly different depending on the mode of transport.

Significant contribution. In 2002, the newly established Climate Impacts Program in the United Kingdom published a list of scenarios that sums up the effects of climate change weather patterns and provides a set of options for addressing them; thus, it contributed formidable research on climate change-related impacts and adaptation strategies (in *Climate Change Scenarios for the United Kingdom*). Besides, Lonergan et al. (1993), Graves and Phillipson (2000), and Giannopoulos et al. (2012) made efforts to contribute to a more specialized approach to adaptation research.

2. Adaptation measures: International guidance, best practices, experience

Suggested adaptation measures summarized during the literature review are clustered based on their content. It is noted that adaptation measures in road transport are expected to monopolize interest in the near future, since they concern the dominant means of transport for everyday mobility in urban and regional areas.

Clustering the adaptation measures summarized the following sub-sections reveals a majority of technical options compared with others. Such solutions are often more straightforward in terms of implementation than organizational or legislative measures, in which potential bureaucracy may result in slow reaction times from the authorities. This result is arguable to be expected because of the reason as mentioned above.

a) Organizational and Decision-Making Processes

Measure A1. Setting and implementation of international standards for weather and emergency information.

Measure A2. Consultation with and coordination of highway authorities, subcontractors, suppliers, and key stakeholders to adjust adaptation strategies.

Measure A3. Establishment of networks of urban, regional, and national stakeholders, transport companies, authorities, and users.

Measure A4. Issuance of educational and information material on emergency cases, planning, and maintenance to related authorities.

Measure A5. Conduct public campaigns in order to raise public awareness regarding local hazard situations.

b) Technical Options

Measure B1. Construction of dikes and creation of flood barriers for protection against water.

Measure B2. Innovative pavement materials resistant to corrosion.

Measure B3. Improved drainage in intersections.

Measure B4. Elevation of coastal road networks.

Measure B5. Design of and investment in new assets with "quick restoration" capability.

Measure B6. Provision of shelters for nonmotorized transport.

Measure B7. Preparation for sufficient salt stocks and road clearing equipment availability before and during winter or storm seasons.

Measure B8. Development of timely communication and coordination plans involving stakeholders and freight operator associations.

Measure B9. Roadside vegetation, absorbing generated heat, protecting roads.

Measure B10. Design of new heat-resistant asphalt mixes.

Measure B11. More heat-resilient bridge joints.

Measure B12. Need for improvement of drainage-sewer systems as well as for more roadside rain pits.

Measure B13. New asphalt mixes help in faster drainage of standing water.

Measure B14. Enhancement of road layers to prevent washing off.

Measure B15. Measures of protection against slope subsidence around road/rail network to avoid cut-off links.

Measure B16. Additional pumping in tunnels.

Measure B17. Installation of windbreaks.

Measure B18. New design standards relating to components of the road network (signs, lighting) enhance users' protection.

Measure B19. Regular clearance of cycle lanes and sidewalks during winter.

c) Procedural and Operational Options

Measure C1. Organization of the supply of trapped drivers/passengers with the help of volunteers and aid organizations.

Measure C2. Adaptation of timetables and service intensities under adverse weather conditions.

Measure C3. Need for alternate routes for freight transport in Arctic areas.

Measure C4. Priority plans that maintain access to hospitals and emergency stations.

Measure C5. Definition of priority routes for road clearance in case of large-scale impacts.

Measure C6. Tracking of "chain reactions" of extreme weather events, particularly in agglomeration areas.

Measure C7. Coordination of emergency plans among transport modes and networks.

Measure C8. Implementation of appropriate risk management procedures in order to be prepared for adverse conditions.

d) Information Flow and ICT Support

Measure D1. Development of sustainable business models for the provision of emergency information systems.

Measure D2. Provision of reliable, instant, and—if feasible—personalized information on the duration of the incident and travel options.

Measure D3. Installation of signs that warn the driver on the upcoming pedestrian flooded network.

Measure D4. Development of intelligent feedback systems in vehicles to communicate user needs.

Measure D5. Adopted operational, physical, technical, procedural, and institutional integration of weather and traffic control services.

Measure D6. Preparation and broad communication on disruptions and alternatives with the public, using a variety of communication channels.

Measure D7. Standardization of weather information and hazard warnings.

e) Decision and Risk Models

Measure E1. Provision of cost-benefit assessment guidelines to logistics companies.

Measure E2. Assessment of logistics companies' risk exposure and establishment of appropriate adaptation plans.

f) Legislative Options

Measure F1. Strict speed limit enforcement during storms.

Measure F2. Review of maintenance contracts and procedures to make them flexible and effective even under rapidly changing weather conditions.

3. Assessment of Adaptation measures

Due to the extent of road networks worldwide and the number of people using them for mobility, any implications would result in millions of lost work hours and various economic and social consequences. In response to that, measures must be taken to tackle this giant, upcoming problem.

It goes without question that maintenance procedure protocols need to be adapted to the ever-changing conditions because the need for servicing networks and infrastructure under the impact of extreme weather events will be severe as the climate gradually changes (Measure F2).

In detail, road networks are at high risk in areas that are likely to be affected by water level rise. Significantly, infrastructure which lies close to the shore should at least be elevated if not relocated or closed permanently (Measure B4).

Increased rainfall could lead to flooding problems in urban and rural networks. Thus, effective draining is crucial. While most road networks have similar draining requirements, intersections are a particular category, which should be treated with special care. The fact that many intersections have mild or non-existent gradients makes the draining of water even harder. As a result, draining should be improved using bigger run-off pipes, unique asphalt mixes (porous asphalt), and more significant storm drains (Measure B3).

Poor draining often results in standing water, which reduces traction and leads to accidents. Speed limits should be strictly applied so as for drivers to have more time to react to possible aquaplaning and to reduce the force of an impact to the driver (Measure F1).

Except flooding, intense rainfalls can cause slope subsidence. In many regions, rainfall slopes, which have not to be stabilized, can subside, leading to rockfalls and mudslides. Minor accidents, closed links, or even human casualties have been reported on such occasions. Thus protective measures should be planned and taken (Measure B15).

Information flow measures are equally necessary as those of a more technical nature. Provision of information to users is very crucial. Public campaigns are a significant mean to raise awareness of users on the possible problems that may arise in the areas they reside in, making them more cautious and familiar with emergency solutions on problems, due to weather phenomenon (Measure A5).

4. Roadmap of Adaptation measures: mainstream climate considerations into transport planning

The proposed roadmap details the order that needs to be followed to enhance the resilience of road transport systems and reduce their vulnerability to climate change impacts. The results of the assessment (Figure 1) were used to place each measure on the appropriate roadmap following the identification of these criteria:

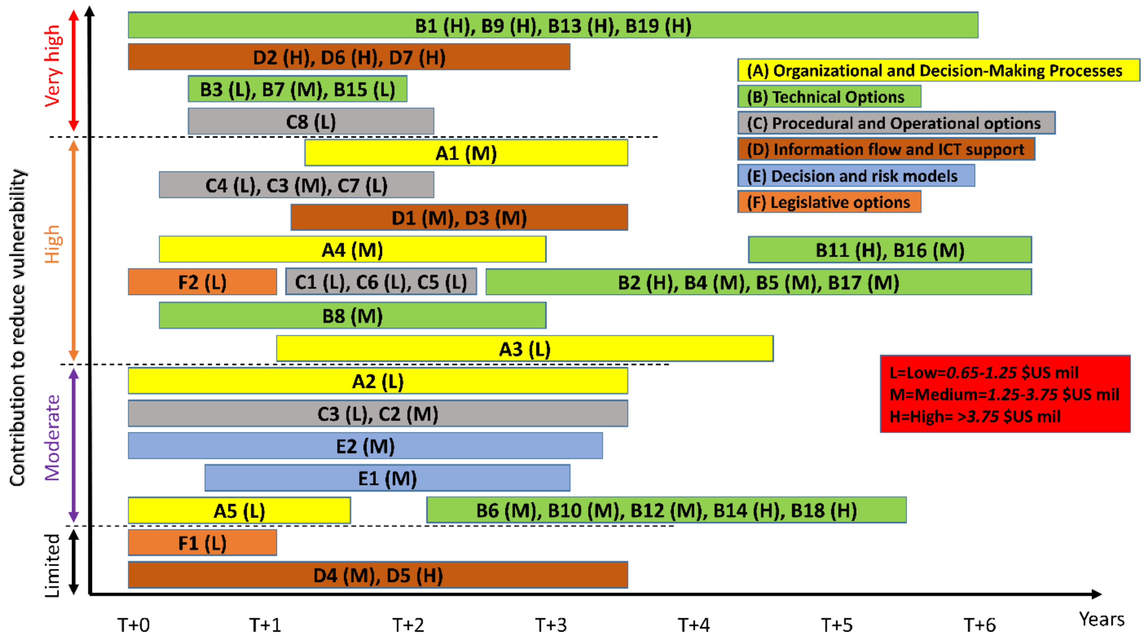
(i) Start of the implementation period (left edge of each measure's box),

(ii) Time needed for its implementation (length of the box on the x-axis),

(iii) Financial resources needed for its implementation (indication on a high-medium-low scale depending on the mode of transport under examination), and

(iv) Contribution of measure to reduced vulnerability and enhanced transport system resilience (placement of box on the y-axis).

FIGURE 1. **Roadmap of adaptation measures in the literature.**



5. Adapted Adaptation measures: Case of Vietnam

The proposed roadmap, as mentioned above, is summarized from international studies. In the case of Vietnam, which has a specific particularity, this roadmap must be adapted. This section discusses the applicability of these measures.

a) Organizational and Decision-Making Processes

Measure A1 requires a review and systematic investigation of international standards. Thus it could be difficult for local consultants in terms of languages, availability, and the possibility to apply, adapt to Vietnamese standards. It would require a longer review process and studies to adopt these standards to fit the Vietnamese context. These studies could be in the form of a Technical Assistant (TA) to help the Ministry of Transport (MOT) and other ministries to achieve relevant outputs. The contribution to reducing the vulnerability is rated High in this case, but a more protracted process is required. The cost to implement this measure is evaluated as Low (from 3 to 5 TAs could be conducted with the given financial frame)

Measure A2, A3, and A4 require exchanges with the authorities, stakeholders, companies. Given that the awareness of climate change in Vietnam is still at the very initial stage, these tasks would be more difficult for all the stakeholders. The contribution to reducing the vulnerability is rated Moderate in this case, but a more protracted process is required. The cost to implement this measure is evaluated as Low for A2, A3, and Medium for A4.

Measure A5 is critical to raise public awareness regarding local hazard situations. However, the contribution to reducing the vulnerability is rated Moderate. For this particular measure, in Vietnam, it is suggested to conduct this measure for a longer time, with a Medium implementation cost. The starting point A5 is proposed at T+0.5 to prepare the content of public campaigns to achieve the highest effectiveness.

b) Technical Options

Measure B1 must be carefully considered, especially in the South of Vietnam (Ho Chi Minh city) and mountainous areas in the North. The priority list for the construction of dikes must be first analyzed, following by the financial plan for the proposed activities. This could require a long process of implementation.

Measures B2, B5, B10 are rated High while applying to Vietnam, especially for the Central, but much effort on research is required. Research projects at MOT's level must be conducted for this measure.

Measures B3, B8, B9, B11, B12, B14, B15, B16, and B18 are found applicable in Vietnam, with the given timing and cost. Measures B9 requires a high cost and lengthy implementation time in Vietnam. Measures B3 and B15 should be placed on the priority list as they are rated as Very High contribution but Low cost. B11 and B16 should be placed at the later phase of the roadmap after carefully verify the technology of the proposed measures.

Measure B4 is, on the contrary, rated as a limited contribution to reducing the vulnerability within the next 10 years in Vietnam. The road networks in Vietnam are less influenced by sea-level rise.

Measures B6, B13 are rated challenging to achieve in Vietnam. With B6, there are limited roads for nonmotorized transport in Vietnam. The traffic stream in Vietnam is a mixture of vehicle types with different sizes, weights, and powers. With B13, an appropriate mix-design should be developed and also standardized.

Measure B7 is found to have limited contribution in Vietnam, or could only be applied in a very few areas (in the North of Vietnam) for salt stocks during winter. Road clearing equipment is also not applicable, given the economic situation of Vietnam. This measure is suggested (by the author) to be removed from the roadmap.

Measure B17 is found to have a limited contribution in Vietnam.

Measure B19 is found not applicable in Vietnam, given the complex traffic situation.

c) Procedural and Operational Options

Measure C1 should be carefully considered, as Vietnamese authorities are familiar with this type of measure.

Measure C3 is found not applicable in Vietnam.

Measures C2 and C4 to C8 should take advantage of international experiences to develop the process, plans, as well as priority plans to deal with extreme weather events. Several TAs or research projects could also be conducted to strengthen the awareness/knowledge of the Vietnamese authorities/stakeholders.

d) Information Flow and ICT Support

Measures D4, D5 are challenging to apply in Vietnam in terms of Information Technology. These could be long-term orientation measures but must go along with the digital transformation process in Vietnam. However, with a medium to high implementation cost, these measures are suggested to perform in the later stage of the roadmap.

Measures D1, D2, D3, D7 could also be started from the earliest stage of the roadmap with several TAs or research projects to be more effective.

Measure D6. Preparation and broad communication on disruptions and alternatives with the public, using a variety of communication channels.

Measure D7 should be developed with cooperation between MOT (DOST, DTS), MIC, MARD and MONRE

e) Decision and Risk Models

Measures E1 and E2 could be long-term measures with several TAs or research projects at MOT's level.

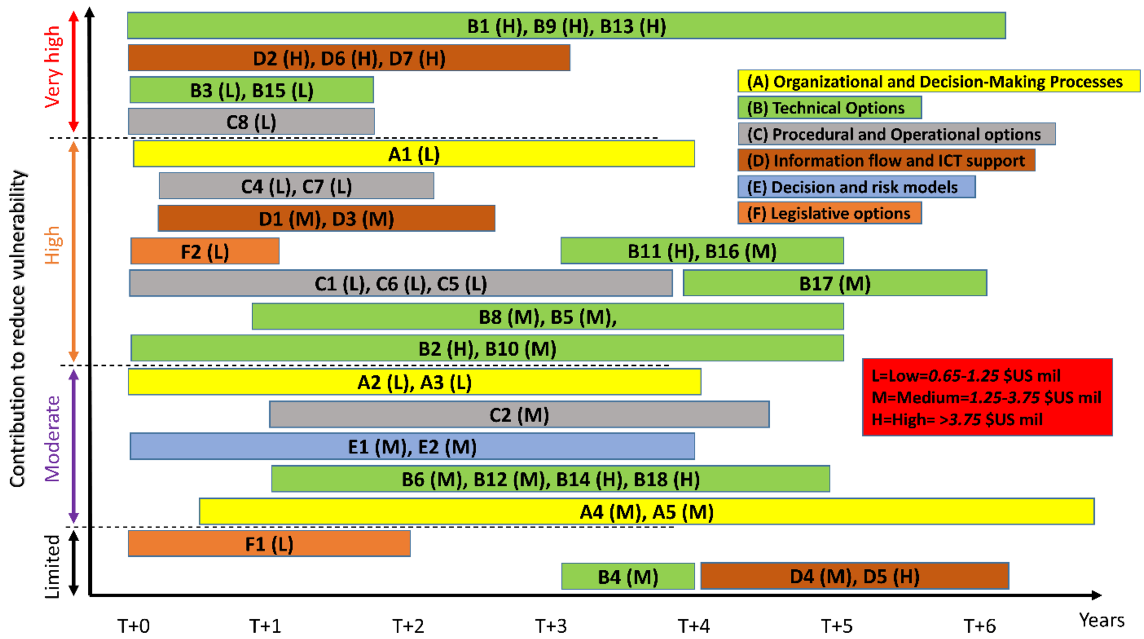
f) Legislative Options

Measures F1 and F2 could be a short-term perspective; however, F1 is limited in terms of efficiency. More attention should be paid to measure F2, as it is rated High contribution.

6. Roadmap of Adapted Adaptation measures for Vietnam

Base on the discussions in the previous section, a roadmap of adapted adaptation measures for Vietnam is proposed herein but might need more discussion to be finalized.

FIGURE 2. **Roadmap of Adapted Adaptation measures for Vietnam**



II. Decision Framework for Addressing the Impacts of Climate Change

1. Transportation Infrastructure

Step 1. Assess how climate changes are likely to affect various regions of the country and modes of transportation.

Step 2. Inventory transportation infrastructure essential to maintaining network performance in light of climate change projections to determine whether, when, and where their impacts could be consequential.

Step 3. Analyze adaptation options to assess the trade-offs between making the infrastructure more robust and the costs involved. Consider monitoring as an option.

Step 4. Determine investment priorities, taking into consideration the criticality of the infrastructure components as well as opportunities for multiple benefits (for example, congestion relief or the removal of evacuation route bottlenecks).

Step 5. Develop and implement a program of adaptation strategies for the near and long terms.

Step 6. Periodically assess the effectiveness of adaptation strategies, and repeat Steps 1 to

WORKING PAPER 9: SHORT NOTE ON CLIMATE RESILIENCE OPTIONS FOR NH19 PRIORITY SECTION

Author: Dr. Jasper R Cook, Tran Viet Hung

A Introduction

1. This short note brings together the key issues relevant to the selection of Climate Change Resilience (CCR) options for NH19 bridges. Comments and recommendations are made on CCR for the 8 identified bridges as well as on CRR implications for other NH19 assets.

B Current Strategic Policy on Climate Resilient Roads in Vietnam

2. Action plan of the Ministry of Transport on proactively responding to climate change, strengthening natural resource management and environmental protection in the period of 2021 - 2025 (Decision No. 452/QD-BGTVT dated March 24th/ 2021) proposes many positive solutions for Climate Change Adaptation, which are specifically summarized as follows:

    - Enhance the resilience to climate change of transport infrastructure by: (a) Integrating the implementation of the national plan to adapt to climate change in the planning and investment planning for transport development in the period 2021-2025, focusing on areas with high vulnerability to climate change, such as the Mekong River Delta and the Northern mountainous region and the Central Highlands; (b) Develop a legal document framework by focusing on reviewing, amending and supplementing standards, regulations and technical guidelines for climate-adaptive transport infrastructure; (c) Research and application of new technologies and construction materials that are capable to adapt to climate change; (d) Mobilizing and attracting financial resources for climate change adaptation; (e) Strengthening capacity of monitoring system for extreme weather to support transport infrastructure management and maintenance; (f) Coordination among ministries and sectors in establishing and sharing database system, monitoring and evaluation system framework, and climate change adaptation planning.
    - Expand the application of non-stop electronic road toll to promote the efficiency of highway network investment, reduce travel time, reduce fuel consumption and mitigate emissions.
    - Effectively manage and use natural resources in transportation infrastructure construction and operation.
    - Enhance environmental protection in the planning, investment, development and maintenance of transport infrastructure.
    - Improve the quality of the preparation of environmental impact assessment reports, environmental protection plans in the preparation of investment projects and maintenance works of transport infrastructure.

- Management, reuse, recycling, encouraging uses of plastic waste in transport infrastructure construction and maintenance

C Road and Bridge Design Standards in Vietnam Relevant to Climate Change Resilience

3. To date no road-specific engineering design guidelines for climate change resilience have formally adopted in Vietnam and Climate Change Resilience (CCR) is not specifically included in Vietnam's engineering design standards for roads and bridges. The two sets of national standards relevant to the engineering design of roads and bridges in Vietnam are TCVN 4054:2005 and TCVN 9845:2013. After the design frequency (return period, or Px) for a structure has been determined with reference to TCVN 4054:2005, the hydrologic calculations based on that frequency are done with reference to formulas specified in TCVN 9845:2013. The existing standards do provide relevant formulas wherein 1 day maximum rainfall (Rx1 Day) value is a key input that can be adjusted for climate change.

4. The national standards for roads and bridges require a design flood level of 1 in 100 years for expressways (P1 or 1%) and 1 in 25 years (P4 or 4%) for category 3, 4, or 5 rural roads; see Table 1 for detail. The 1-day annual maximum rainfall total (Rx1day) is identified as the critical variable in all formulas for hydrologic calculations of design water discharge, flood level, and flow velocity. Under certain undefined technical conditions the return periods can be adjusted (eg 4% to 1%) however it appears that this is not allowed for purely financial budget or cost constraint reasons.

TABLE 1. **Design Frequencies (Px values) to be applied to Different Road Categories and Assets (TCVN 4054)**

Road Asset	Road Category		
	Expressway	I & II	III, IV, V
Medium and large bridges	P1 (1 in 100 RP)	P1 (1 in 100 RP)	P1 (1 in 100 RP)
Small bridges and culverts	P1 (1 in 100 RP)	P2 (1 in 50 RP)	P4 (1 in 25 RP)
Interception and side drainage	P4 (1 in 25 RP)	P4 (1 in 25 RP)	P4 (1 in 25 RP)

Notes:
Large bridge: LC >100m; Medium Bridge: 25m LC < 100m; Small Bridge: LC < 25m.
Where LC is linear distance between the two abutments.
NH 19 is designated a Class III road.

D Guidance from MoT and MoNRE Adopted by Consultants on CCR for NH19

5. In their Climate Resilience Report the Consultants quoted a number of guidance points from MoT and MoNRE; these include (*edited for English*):

- The RPC 8.5 climate change scenario should be applied NH19 as "permanent works".

- Determination of (adaptation) level must be based on practical needs and resources that are available
- . The design life of the Works should be used to select the relevant period of time for the determination of climate change impact.
- It may be necessary to consider the implementation phasing of the Works in order to achieve solutions to cope with climate change (e.g embankment elevation).
- Calculations for sea level rise and change in rainfall should be defined in accordance with the current technical standards.(i) Select the average value of sea level and precipitation of the base period 1986-2005 for the geographical area of the Works; (ii) Select sea level rise, rainfall change for scenario of climate change & sea level rise according to the appropriate period and the time for the geographical area of the Works; (iii) Sea level height = value (i) + value (ii); Rainfall = value (i) X (100 + value (ii))/l 00.
- Compare the parameters that is identified as mentioned in the Item a, b and to carry out the design solutions

6. The consequence of the above guidance is that maximum values of CRR adaptation have been selected by the Consultants for design of large bridges based on:
   - Most conservative climate change scenario (RCP 8.5)
   - Maximum design frequency P1 (1:100 RP)
   - Climate change for 2099

7. CCR calculations commissioned by the Consultants based on the above criteria and using 3 selected climate models (cnrm-cm5, GFDL-cm3, H4Dcem2-es) resulted in very high deck levels for the selected bridges. A comparison with the World Bank Climate Portal (WBCP) figures and comparing these RCP 4.5 outputs with the Consultants RCP 4.5 outputs showed very significant differences. The WBCP outputs are based on using median figures from the 10-90% percentile of 16 climate models (Annex B)

E Research and Applied Practice Relevant to NH19 CRR

8. Recent ADB-funded work in Vietnam has been undertaken on resilience options for infrastructure that is relevant to NH19[2] [3]. Some key points are:
   i. A regional climate model (e.g., PRECIS13) can be successfully run for a delineated sub-region in which the boundary conditions are derived from a parent GCM.
   ii. RCP 8.5, although recommended by MoNRE, represents the most conservative assumptions on limiting future global greenhouse gas emissions.

2 ADB. 2020a. Climate-Change Adjustments for Detailed Engineering Design: With Worked Examples from Viet Nam. Manila.

3 ADB. 2018. Adjusting Hydrological Inputs to Road Designs for Climate Change Risk Guidelines to Apply Extreme Value Analysis. ADB Knowledge Product ADB PPTA 8957. Manila

iii. There is a significant challenge in using climate change data for medium to large sized bridges that require a design to withstand 1% (1 in 100 years extreme events) as these bridges often have limited capital investment available which in turn limits the resources for design assessment and implementation.

iv. Historical hydrometeorological records do not adequately represent the extreme climate conditions lying in store for long-lived structures, however, climate models can yield reliable information about changes in extreme-weather at the scale needed for engineering design.

v. The scientific uncertainty attached to some CCR parameters is significant, especially for extreme events with long (>20-year) return periods. This uncertainty is due in part to low confidence in the ability of climate models to simulate natural variability and changes in extreme weather phenomena (e.g., tropical cyclones) at the scale of interest. Therefore, when deriving adjustment factors for Final Engineering Design, a precautionary approach is recommended.

vi. The key change regarding CCR analysis is the move from the use of historical climate records for input parameters to the Vietnam standards to using projected climate records inclusive of climate change. There is a clear risk of infrastructure under-design and life-time vulnerability in relying on historical rainfall data. The key question is the level of CCR to be adopted, which should be an economic and engineering balance between: current cost, whole-life cost, acceptable climate risk, socio-economic impact; good engineering and National Policy. Historical rainfall intensity-frequency-duration (IFD) relationships are likely to be increasingly unreliable predictors of future flood levels

vii. A major assumption is that there is a close and consistent relationship between flood level and daily maximum rainfall levels, however for sites of medium to large bridges typically involving relatively large drainage basin areas the relationship between Px rainfall and Px flood level is noted as being possible weak.

viii. For the more extreme events of P1 the specification of flood levels is complicated by the range of parameters that influence the flood levels including: size of the basin/catchment, the topographic and land forms within the catchment including terrain, rock and soil composition, and current land use including the vegetation cover. In many circumstances the preferred approaches specified in the TCVN and TCN regulations are insufficient to provide the data required by designers.

F Identified CRR Options for CCR NH19 Bridge Design.

9. Table 2 lists the 8 bridges identified for reconstruction under the NH19 Priority Stage. Four had been selected for design with 1 in 25 return periods (P4) and four with 1 in 100 return period (P1), however it is possible that because of the widened spans only 1 is now eligible for P4 design.

TABLE 2. **Identified Bridges**

No.	Name of bridge	Existing Bridge Centre Deck level	Existing bridge span	Proposed Bridge Span	Design Frequencies (As reported)	Design Frequencies (Possible revision)
1	Bầu Sen	27.80	1x9m	1x15m	P4	P4
2	Ba La	28.89	7x13m	3x33m	P1	P1
3	Ta Ly	425.70	2x10m	1x33m	P4	P1
4	Thầu Dầu	416.36	3x12m	2x24m	P1	P1
5	Linh Nham	672.76	3x12m	2x33m	P1	P1
6	Vàng	685.52	1x12m	1x33m	P4	P1
7	Lệ Cần	695.45	1x11m	1x24m	P4	P1
8	An Mỹ	700.24	2x12m	2x24m	P1	P1

10. The CCR options considered are listed in Table 3 largely in terms of bridge deck levels and in consequence the impact of climate change on flood levels and cutting of access. Brief comments are as follows

i. Option 1. This is assumed to be based on historic flood levels up to 2020, without additional overflow protection. There would be no rational CCR basis for selecting this option.

ii. Option 2. This is the design as submitted at FS. There is no clear definition of the CRR level or the amounts of over-top protection

iii. Option 3. This is an arbitrary increase but takes into account the apparently much lower (R1xDay) increases using the WBCP.

iv. Option 4. This extreme lowest-risk CRR case is not practically feasible in terms of the cost of the high bridge deck levels as well as the social and engineering implications of approach embankments within the current project framework

TABLE 3. **CRR Option Summary in Terms of Deck heights**

			Option 1 - 2020 without protection		Option 2 - Feasibility Study			Option 3 Assumed a 20% Increase in Flow			Option 4 Extreme CCR Levels using RDC 8.5		
No.	Name of bridge	Existing Bridge Deck Level (m)	Design Bridge Centre Deck level (m)	Height above existing bridge (m)	Design Bridge Centre Deck level (m)	Height above existing bridge (m)	% increase in Flow on 2020	Design Bridge Centre Deck level (m)	Height above existing bridge (m)	% increase on 2020	Design Bridge Centre Deck level (m)	Height above existing bridge (m)	% increase on 2020
1	Bầu Sen	27.80	30.47	2.67	30.75	2.95	93	30.51	2.71	20	32.93	5.13	162
2	Ba La	28.89	33.2	4.31	33.55	4.66	11	33.43	4.54	20	35.51	6.62	224
3	Ta Ly	425.70	427.74	2.04	427.47	1.77	-17	428.01	2.31	20	430.14	4.44	284
4	Thầu Dầu	416.36	418.29	1.93	418.33	1.97	-12	418.93	2.57	20	425.17	8.81	309
5	Linh Nham	672.76	675	2.24	675.93	3.17	15	675.48	2.72	20	679.18	6.42	274
6	Vàng	685.52	689.72	4.2	689.31	3.79	-7	690.16	4.64	20	692.39	6.87	239
7	Lệ Cần	695.45	698.7	3.25	698.55	3.1	0	699.06	3.61	20	701.12	5.67	232
8	An Mỹ	700.24	702.46	2.22	702.28	2.04	-53	702.69	2.45	20	706.34	6.1	266

G CRR Design implications of selected option for NH19

11. It is understood that TCMQ wish to reamin with the existing FS design (Options 2), largely in response to concerns as to the implication of seeking approval for additional budget allocation for CCR adaptations. The implication of this selection is that there is a significant risk of bridge overtopping within its design life. On the basis of the Consultants interpretation and analysis of future (R1XDay) increases this risk will increase as climate change impacts increase towards the end of the century (the basis of the RCP 8.5 scenario).

H Option 2 Relevance to Strategic Policy

12. The national strategy clearly indicates that the Vietnam road network should be increasingly resilient to future climate impacts. It is essential therefore that the design of NH19 must be demonstrably "climate resilient"; the key issue is to what level this should be. For NH19 bridges, given the impracticality of constructing a bridge deck levels based on the extreme interpretation of the RCP8.5 scenario, it is logical to seek an option that involves a compromise of lower deck levels and overtopping protection. In this context the selection of "Option 2" could be acceptable if the additional risk is justified and mitigated as much as possible.. This justification could be by showing how the RCP 8.5 level of CCR requirements is achieved by uisng a lower alignment heightening with the remaining risk up to the RCP 8.5 level being taken care of by protection measures. Looking at in percentage terms; that is, if Option 4 bridge level are considered a 100% CCR level, then the compromise lower level design absorbs a significant part of the CCR risk with the remaining less likely risk absorbed through over-topping protection. Hence the design is shown to be complying with the RCP8.5 scenario through realistic methods. Table 4 and 5 show the percentages of risk in terms of levels and flow taken by Options 1-3.

TABLE 4. **Option Deck levels as a Percentage of the Extreme Model Option**

		Option 1			Option 2			Option 3			Option 4		
Bridge	Existing deck height (m)	Bridge Deck Level (m)	Difference from existing (m)	% of maximum CR level (m)	Bridge Deck Level (m)	Difference from existing (m)	% of maximum CR level (m)	Bridge Deck Level (m)	Difference from existing (m)	% of maximum CR level (m)	Bridge Deck Level (m)	Difference from existing (m)	% of maximum CR level (m)
Bau Sen	27.8	30.47	2.67	**52.0**	30.75	2.95	**57.5**	30.51	2.71	**52.8**	32.93	5.13	**100**
Ba La	28.89	33.2	4.31	**65.1**	33.5	4.61	**69.6**	33.4	4.51	**68.1**	35.51	6.62	**100**
Ta Ly	425.7	427.74	2.04	**46.4**	427.47	1.77	**40.2**	428	2.3	**52.3**	430.1	4.4	**100**
Thau Dau	416.36	418.29	1.93	**22.1**	418.33	1.97	**22.5**	418.9	2.54	**29.1**	425.1	8.74	**100**
Linh Nham	672.76	675	2.24	**34.8**	675.93	3.17	**49.2**	675.5	2.74	**42.5**	679.2	6.44	**100**
Vang	685.52	689.72	4.2	**61.0**	689.31	3.79	**55.1**	690.2	4.68	**68.0**	692.4	6.88	**100**
Le Can	695.45	698.7	3.25	**57.5**	698.55	3.1	**54.9**	699.1	3.65	**64.6**	701.1	5.65	**100**
An My	700.24	702.46	2.22	**36.6**	702.28	2.04	**33.7**	702.7	2.46	**40.6**	706.3	6.06	**100**

TABLE 5. **Option Flow Levels as a Percentage of the Extreme Model Option**

Bridge	Option 1			Option 2			Option 3			Option 4
	Discharge Design Q (m3/s)	Difference from maximum (m3/s)	% of maximum flow	Discharge Design Q (m3/s)	Difference from maximum (m3/s)	% of maximum flow	Discharge Design Q (m3/s)	Difference from maximum (m3/s)	% of maximum flow	Discharge Design Q (m3/s)
Bau Sen	20.4	33.1	**38.1**	39.47	14.03	**73.8**	24.48	29.02	**45.8**	53.5
Ba La	672.3	1507.2	**30.8**	747.18	1432.32	**34.3**	806.76	1372.74	**37.0**	2179.5
Ta Ly	75	213.3	**26.0**	62.19	226.11	**21.6**	90	198.3	**31.2**	288.3
Thau Dau	317.1	978.7	**24.5**	278.42	1017.38	**21.5**	380.52	915.28	**29.4**	1295.8
Linh Nham	282.3	772.8	**26.8**	240.64	814.46	**22.8**	338.76	716.34	**32.1**	1055.1
Vang	68.5	163.4	**29.5**	63.75	168.15	**27.5**	82.2	149.7	**35.4**	231.9
Le Can	61.4	142.5	**30.1**	61.17	142.73	**30.0**	73.68	130.22	**36.1**	203.9
An My	237.4	632.5	**27.3**	112.34	757.56	**12.9**	284.88	585.02	**32.7**	869.9

I CCR for Pavement Levels and Culvert Design

13. After bridges, the most important other concerns are: (i) culvert placements and their protection against increased water flows, (ii) road foundation strength and provisions to prevent water ingress and consequent weakening leading to pavement failure, , (iii) earthwork slope protection and (iv) provision of proper end-outfalls for lateral ditches.

14. As specified in TCVN 4054:2005 the design elevation of the road sections running along riverbanks, approaches to small bridges, culverts, and flooded fields must be at least 0.50m higher than the flood water level at the design frequency specified for the type of structure

J Implications for non-priority sections – An Khe Pass.

15. The principles and issues outlined in this note are also applicable to the other sections of NH19 and in particular to the geotechnically difficult An Khe Pass. The World Bank have already (during FS) identified a number of level 4 and level 5 geotechnical hazards. These need to be comprehensively addressed using a combination of geotechnical and climate impact analyses.

K Summary

16. There is a strategic policy requirement to ensure that the design of NH19 assets, including bridges, is "climate resilient", although the level of resilience is neither defined or detailed in terms of adaptation options in the relevant road and bridge standards.

17. The Consultants have analysed, or commissioned analyses, of future climate indices (specifically RX1Day rainfalls) using very conservative parameters, as recommended by MoNRE. These analyses appear to contrast with less conservative outputs from the WBCP using similar models.

18. The highly conservative Option 4 is not considered a practical engineering option and a compromise CCR solution involving a combination of moderately heightened alignment and overtopping protection measures (including an erosion resistant pavement for the bridge and approaches) is suggested as practical way forward.

19. Some clarification is required on the return period (Px value) to assigned to bridges that have increased spans over tjhose currently in place.

20. A compromise option such as indicted by Options 2 or 3 offer a reasonable **solution provided they can be more formally justified in terms of its CRR level and storm return period, using a combination of alignment level and erosion/over-topping protection.**

21. Suggested actions include a review of the extreme conservative analysis for option4 and a "what-if" or sensitivity analysis on the reduction to RCP 4.5 and/or reduction of time period to place Options 2 and 3 in terms of CRR "level".

22. Proceed with design and costing of "overtopping protection measures". Given the risk of overtopping will increase later in the design life of the structures some consideration could be given to this overtopping being of a time-phased cost and construction nature. This will depend to some extent on how the options 2 or 3 can be placed in terms risk level.

Short Note on Climate Resilience Options for NH19 Priority Section

Annex A: Clarifications on Climate Change Action Plan

1. Decision No. 2139 / QĐ-TTg dated December 5, 2011 of the Prime Minister approving the National Strategy on Climate Change;

2. Decision No. 1474 / QĐ-TTg dated October 5, 2012 of the Prime Minister promulgating the National Action Plan on climate change for the period of 2012-2020;

3. Decision No.1456/QĐ-BGTVT dated May 11, 2016 of the Minister of MoT promulgating the Action Plan for Climate Adaption and Green Growth;

4. Decision No. 622 / QĐ-TTg of the Prime Minister promulgating the National Action Plan for implementation of 2030 Agenda for Sustainable Development

5. Decision No. 2707 of December 17, 2018 of MoT Minister on the MOT's Action Plan for implementing the 2030 Agenda of Government for Sustainable Development.

6. Circular No. 70/2018/TT-BTC on management and use of recurrent budget for national target program of climate adaption and green growth.

7. Decision No.1456/QĐ-BGTVT dated May 11, 2016 of the Minister of MoT promulgating the Action Plan for Climate Adaption and Green Growth;

Vietnam's Nationally Determined Contribution:

Mitigation of Greenhouse Gas Emissions in the Transport Sector

- E19. Promotion of biofuels for vehicles
- E20. Promotion of CNG buses in transportation

World Bank Support Team

Final Report

Hanoi, October 2021

WORLD BANK GROUP

Vietnam's Nationally Determined Contribution: Mitigation of Greenhouse Gas Emissions in the Transport Sector

E19. Promotion of biofuels for vehicles

E20. Promotion of CNG buses in transportation

Vietnam's Nationally Determined Contribution: Mitigation of Greenhouse Gas Emissions from the Transport Sector

E19. Promotion of biofuels for vehicles

E20. Promotion of CNG buses in transportation

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Hanoi, October 2021

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Acronyms

BAU	business as usual
BMU	Federal Ministry of the Environment, Nature Conservation and Nuclear Safety
CAGR	compound annual growth rate
CNG	compressed natural gas
DOF	Department of Finance
DONRE	Department of Natural Resources and Environment
DOT	Department of Transport
DPI	Department of Planning and Investment
GHG	greenhouse gas
GSO	General Statistics Office of Vietnam
EFFECT	Energy Forecasting Framework and Emissions Consensus Tool
IKI	International Climate Initiative
LPG	liquefied petroleum gas
MOIT	Ministry of Industry and Trade of the Socialist Republic of Vietnam
MONRE	Ministry of Natural Resources and Environment of the Socialist Republic of Vietnam
MOST	Ministry of Science and Technology of the Socialist Republic of Vietnam
MOT	Ministry of Transport of the Socialist Republic of Vietnam
NDC	Nationally Determined Contribution
TraCS	Advancing Transport Climate Strategies
UNFCCC	United Nations Framework Convention on Climate Change
VNEEP	Vietnam Energy Efficiency Program

Summary

In Vietnam, the transport sector contributed 18 percent of energy-related greenhouse gas (GHG) emissions in 2014, mostly from road transport. The adoption of biofuel blended vehicles, natural gas vehicles (NGVs), and electric vehicles (EVs) is an important strategy to reduce emissions from the transportation sector.

In the first stage of its low-carbon transport strategy, Vietnam has set a target of adding 623 compressed natural gas (CNG) buses and an average annual output of 145,000 cubic meters (m^3) of ethanol for transportation by 2030. The Ministry of Transport (MOT), which is responsible for managing the transport sector, promotes the use of clean energy to mitigate GHG emissions and local pollutants. Although the plan to promote CNG buses and biofuel usage is established at the central level, its success depends on the local governments because they have to develop a regulatory framework to enable the adoption of clean-energy vehicles and deploy public charging infrastructure.

Vietnam has approximately 70 million vehicles (NTSC 2020). Two-wheelers account for more than 90 percent of the vehicles. In 2019, E5 gasoline accounted for 38 percent of the total gasoline consumption. Public buses were the first adopters of CNG. In 2020, 672 CNG buses accounted for 5 percent of Vietnam's bus fleet. These outcomes have already met the Nationally Determined Contribution (NDC) commitments for emissions reductions using domestic financial resources by 2030. However, give the projected increase in fuel consumption, additional efforts are required to raise the level of these targets by 2030.

This study simulates the impacts expected from the implementation of the demand/supply side policy instruments on biogasoline and CNG bus penetration in Vietnam. The biogasoline market share and number of CNG buses are evaluated in two scenarios: the business-as-usual (BAU) and the mitigation reduction (NDC-Deep Dive; NDC-DD) scenarios. The BAU scenario includes all policies and interventions in the biofuel and public transport subsector that were enacted up to and including the base year of 2014, with no additional deployment of policies and measures during the period from 2014 to 2030. The NDC-DD scenario analyses the impacts of policy interventions promulgated after 2014 and additional policy measures that were deemed necessary to deliver on NDC targets (mostly policies that are already in the government's pipeline).

Scenarios are presented in Tables 0.1 and 0.2. For biofuels, the scenario shows that the proportion of E5 gasoline will tend to decrease slightly in the period from 2020 to 2024 and decrease to 30 percent by 2024. E10 gasoline will be used in the road transport sector by 2025. It is assumed that the amount of ethanol used for E10 gasoline in 2025 will be equal to the amount of ethanol used for E5 gasoline in 2024. The share of E5 gasoline is expected to be 30 percent in 2024, so it can be inferred that the share of E10 gasoline will be 15 percent by 2025. The share of E10 will gradually increase to 30 percent by 2030.

Regarding CNG buses, the scenario indicates that tax incentives, subsidies, and availability of filling stations are the most important tools to promote fleet size development. By implementing the subsidy mechanism and the expansion of the CNG filling station system, the size of the CNG bus fleet is expected to reach 2,200 units by 2030.

With additional efforts, the impact of biofuels would be improved compared to the NDC commitment and World Bank's 2019 report, 1.03 percent CO_2 emissions reduction compared to 0.6 percent in the NDC (Oh et al. 2019) by 2030. The impact is more significant in the long term (after 2030). The reduction in GHG emissions would be even higher if the use of E10 gasoline is promoted.

TABLE 0.1. **CO_2 Emissions Reduction through Biofuel Penetration**

	2014	2020	2025	2030
BAU	26,416	38,002	52,404	72,053
Emissions reduction scenario (NDC-DD)				
CO2 emissions	26,416	37,757	52,126	71,315
% CO2 emissions reduction (compared to BAU)	0.00%	0.65%	0.53%	1.03%
NDC scenario				
CO2 emissions	26,416	37,656	51,963	71,566
% CO2 emissions reduction (compared to BAU)	0.00%	0.92%	0.85%	0.68%

Source: Study team.

Note: This calculation does not include the GHG emissions derived from producing and transporting the ethanol, and only takes into account CO_2 emissions of road transport. Data presented in thousand tons.

The impact of CNG bus penetration would also be more significant compared to the NDC commitment and the World Bank's 2019 report (Oh et al. 2019) by 2030. Under the moderate scenario, 47,900 tons CO_2 (tCO_2) will be avoided in 2030, compared to 4,300 tCO_2 under the NDC commitment and the World Bank's 2019 report.

TABLE 0.2. **CO_2 Emissions Reduction through CNG Bus Penetration**

	2014	2020	2025	2030
BAU	686.6	1,334.9	1,767.4	2,133.5
Emissions reduction scenario (NDC-DD)				
CO2 emissions	686.6	1,321.7	1,736.5	2,085.6
% CO2 emissions reduction (compared to BAU)	0.0%	1.0%	1.8%	2.3%
NDC scenario				
CO2 emissions	686.6	1,321.7	1,757.9	2,129.2
% CO2 emissions reduction (compared to BAU)	0.0%	1.0%	0.5%	0.2%

Source: Study team.

Note: CO_2 emissions in these scenarios only consider public transport. Data presented in thousand tons.

In order to implement the road map on biofuel and CNG bus deployment, this study recommends the following policy interventions that can be applied to promote the growth of clean-energy vehicles in Vietnam:

* **Feedstock supply for the production of ethanol:**
  - **The period from 2021 to 2025:** Retain existing orientation policies for volume and plantation area of cassava (i.e., 10–11 million tons and 500 hectares, respectively) as well as incentives for cassava farming and processing in accordance with Decree No. 55/2015/NĐ-CP on "Credit Policy for Agricultural and Rural Development" and Decision No. 68/2013/QĐ-TTg on "Supportive Policy for Mitigation of Losses in Agricultural Sector." Additionally, it is necessary to formulate a plan for a dedicated feedstock area for domestic ethanol plants.
  - **The period from 2026 to 2030:** Alternative feedstock (e.g., industrial crops) must be considered when demand for ethanol is increased. In existing policies, only cassava is selected as feedstock for the production of ethanol. It is necessary to formulate and promulgate policies regarding alternative feedstock for the production of ethanol in Vietnam.

* **Supply of ethanol:** The mechanism of linking farming and processing to consumption of cassava products should be formulated by utilizing incentives in accordance with Decree No. 98/2018/NĐ-CP on "Incentive Policies for Development of Linkage in Production and Consumption of Agricultural Productions." This may lead to a stable feedstock supply for domestic ethanol plants. Additionally, there will be a growth of demand for ethanol as a result of the shift from E5 gasoline to E10 gasoline. Existing ethanol plants need to scale up capacity (for plants with stable operations) or restart their operations (for plants with discontinuous operation due to financial loss). Hence, it is necessary to provide loans with preferential interest rates to existing ethanol plants for capacity expansion or reoperation.

* **Biogasoline supply:** Key traders of gasoline need to invest and expand the capacity of the blending system in response to the shift from E5 gasoline to E10 gasoline. In order to encourage these traders to expand the capacity of the blending system, incentives, such as an exemption from import tax on machines and equipment used for blending biogasoline, should be provided. The Ministry of Natural Resources and the Environment (MONRE) must promulgate the list of imported machinery, equipment, vehicles, tools, and supplies used for environmental protection in accordance with Decree No. 134/2016/NĐ-CP "Guidelines for the Law on Export and Import Tax."

* **Biogasoline consumption:** The Vietnamese government should provide purchasing incentives that can further increase the price gap between less-expensive biogasoline and conventional gasoline, such as reducing value added tax (VAT), Environmental Protection Tax (EPT), and Special Consumption Tax (SCT).

The policy recommendations for achieving 2,199 CNG buses in urban fleets by 2030 are:

* Increase investment in public filling station infrastructure through private partnerships. Policies related to investment in CNG filling stations need to facilitate viable business models with attractive payback periods to attract private investment

* Provide solutions to encourage investment in CNG buses or create a differentiating advantage between investing in CNG buses and buses using diesel fuel; for example, providing tax exemptions if enterprises invest in CNG buses

* Establish a mandatory fuel economy standard to reduce transport emissions while CNG buses are not yet competitive.

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I. Introduction

1.1 Background

Per capita greenhouse gas (GHG) emissions in Vietnam are moderate in absolute terms compared to the global average. However, even though the economy's carbon intensity is declining, increasing per capita income is driving the demand for energy consumption, which would lead to continued growth in carbon intensity over the coming decades. Vietnam is the thirteenth most carbon-intensive economy globally and the fourth among low- and middle-income countries in East Asia (Olivier et al. 2016). From 2000 to 2015, CO_2 emissions nearly quadrupled. A fast-growing transport sector provides a significant contribution to rising GHG emissions. Transport GHG emissions have been rising with increasing motorization and are expected to more than double from 38.5 million tons to 89.1 million tons between 2016 to 2030. Freight transport increased by more than the average annual 12 percent between 1995 and 2006, and road transportation volume tripled from 2005 to 2013 (GSO 2014). Car and motorcycle ownership grew by 122 percent and 233 percent, respectively, during the first decade of the twenty-first century.[1] Several studies estimate that passenger and freight transport demand will increase by 9 to 10 times by 2030 from 2005 levels.

Vietnam is committed to addressing climate change mitigation challenges. Vietnam's Nationally Determined Contribution (NDC) under the United Nations Framework Convention on Climate Change (UNFCCC) sets GHG emissions reduction targets for the post-2020 period. Vietnam's first NDC established GHG emissions reduction targets of 8 percent below business as usual (BAU) between 2021 and 2030, and up to 25 percent reduction, conditional on international support. In accordance with Decision 1/CP.21 of COP21, requesting parties to communicate or update the NDC by 2020, Vietnam reviewed and updated its NDC. In the revised NDC, Vietnam committed to a 9 percent GHG emissions reduction by 2030 compared to BAU, with domestic resources. This contribution can be raised to 27 percent GHG emissions reduction against BAU, with international support.[2]

In the updated NDC report for 2020, measures to mitigate GHG emissions from the transport sector using only domestic resources include: improving energy efficiency and efficiency, reducing fuel consumption; modal shift from private to public transport; modal shift from road freight transport to inland waterway and coastal waterway; and fuel shift to encourage the development of electric motorcycles, promoting the use of biofuels, CNG gas, and other clean fuels.

The World Bank, in collaboration with the GIZ with contributions and support from its partners, has provided technical assistance to Vietnam's Ministry of Transport (MOT) for the purpose of delivering a vision and strategies to reduce the carbon footprint of the transport sector. The results of the analysis are presented in the World Bank's Working Paper "Addressing Climate Change in Transportation: Volume 1: A Pathway to Low-Carbon Transport" (Oh et al. 2019). The results of this study have significantly supported the update of NDC 2020. In the World Bank study, four scenarios were developed and analyzed: BAU and mitigation scenarios 1, 2, and 3. Scenario 1 includes some policies and measures that would be implemented only with domestic resources; scenario 2 is confined within the scope of the policies but would require international sources; and scenario 3 includes ambitious measures outside the existing policies. Results show that under BAU conditions, transport sector CO_2 emissions would be 89.1 million tons in 2030. However, under the mitigation scenario 1, the sector's CO_2 emissions in 2030 would reduce by 8 million tons CO_2—a 9 percent reduction compared to BAU achieved through the combination of the following measures:

- E15. Improvements in vehicle fuel efficiency
- E16. Modal shift from private to public transport
- E17. Freight model shift from road to inland and coastal waterways
- E18. Promotion of electric two-wheelers
- E19. Promotion of biofuels
- E20. Promotion of CNG buses

Among the above mitigation measures, the interventions "E19 – Promotion of biofuels" and "E20 – Promotion of CNG buses" are relatively well quantified in the emissions reduction target. Specifically, shifts toward lower-carbon fuels (compressed natural gas, or CNG, used in 623 urban buses, ethanol E5 in 40 percent of gasoline sales up to the supply cap for ethanol of 145,000 m^3) reduce the sector's CO_2 emissions by 3.55 million tons of CO_2 during the period from 2015 to 2030. Table 1.1 illustrates the results of the two measures.

TABLE 1.1. **Reduction of CO_2 Emissions by Two Mitigation Options Under Domestic Resources**

Mitigation Measures	2014	2020	2025	2030	Cumulative Reduction 2014–30
E19. Promotion of biofuels	0	256	269	267	3,487
E20. Promotion of CNG buses	0	5	5	3	64
Total	0	261	274	270	3,551

Source: Oh et al. 2019.

Note: Data in thousand tCO_2.

Measures to reduce GHG emissions using domestic resources are currently being reviewed by the MOT to assess the progress and efforts of the transport sector in implementing the NDC commitments as well as consider the possibility of further promotion of GHG emissions reduction in the transport sector. In parallel with other projects (e.g., the VN-SIPA project that conducts an assessment of the modal shift from private to public transport funded by GIZ), the MOT continues to conduct research to concretize two measures—E19 and E20—on the basis of updating input data, deploying detailed surveys on biofuel supply and demand and CNG buses, and is developing further policy road maps to promote the deployment of biofuels and CNG buses.

1.2 Objectives

The overall goal of this consultancy is the provision of technical assistance to the MOT to identify deployment measures at the national or local level, as appropriate, and update the estimation of GHG emissions for:

The promotion of biofuel for vehicles

The promotion of CNG buses in transportation.

The specific objectives of the study include:

Evaluation of the implementation results of measures E19 and E20 in the period from 2015 to 2020

Analysis of the trends and prospects of biofuels and CNG buses on the basis of domestic and international experience analysis, supply-demand analysis from policy and market perspectives

Calculation and comparison of GHG emissions between the proposed scenario (NDC-DD) and the business-as-usual (BAU) scenario and the NDC scenario using the domestic resource (or scenario 1 in the World Bank's 2019 study)

Proposal of an implementation road map to ensure the promotion of biofuels and CNG buses.

1.3 Scope of the Study

As a stated objective, the scope of this study will be limited to the use of biofuels for road motor vehicles and the use of CNG buses in public transport. The following section describes the main tasks and contents of the activities and the method of performing the tasks.

1.3.1 E19. Promote the use of biofuels for vehicles

- Subjects: all types of road motor vehicles using gasoline fuel (excluding vehicles running on diesel fuel)
- Coverage: nationwide
- Time period: calculate and develop a road map for implementation to 2030
- Number of scenarios: only one scenario is mentioned with domestic resources

1.3.2 E20. Promote the use of CNG buses in transportation

- Subjects: CNG buses
- Coverage: five central cities (Hanoi, Ho Chi Minh City, Da Nang, Hai Phong, and Can Tho) and one province with high potential to use CNG buses (Binh Duong)
- Time horizon: calculate and build a road map for implementation to 2030
- Number of scenarios: only one scenario is mentioned with domestic resources

1.4 Calculation Method

The method used is modeling with the EFFECT software tool—this tool was previously used to prepare NDC reports of the transport sector—in which computational steps are simulated according to the sequence of traffic activities using a bottom-up microsimulation technique.

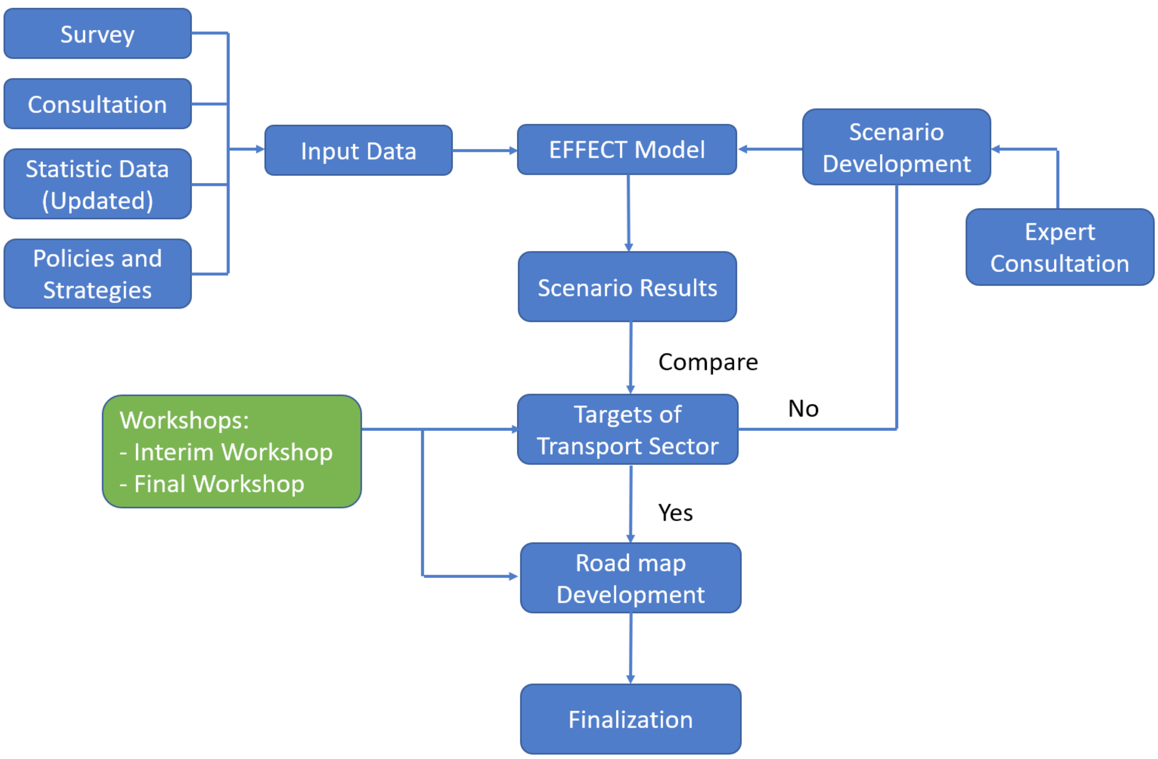
The general socioeconomic input data system collected and updated from available data sources and related projects is currently being implemented by the MOT and line ministries.

The data system related to the supply and demand of biofuels and CNG buses is collected from existing statistical data sources, combined with actual surveys (interviews with stakeholders).

In this study, two scenarios were developed and analyzed—BAU and mitigation scenario with domestic resources. BAU includes the base year of 2014, which has been uniformly used across the updated NDC and relevant projects. The mitigation scenario consists of policies and measures in the existing master plan and would be implemented only with domestic resources. The mitigation scenario in this study (the so-called NDC-Deep Dive scenario) would be compared to scenario 1 in the World Bank's 2019 study and the scenario using the domestic resources in the updated NDC to assess the more ambitious level of the transport sector.

The targets of GHG emissions reduction through the mitigation measures and policies will be discussed in internal consultation between the World Bank team, the MOT, and other stakeholders.

FIGURE 1.1. **Overall Framework Flow**



Source: Study team.

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Olivier, Jos G.J., Greet Janssens-Maenhout, Marilena Muntean, and Jeroen A.H.W. Peters. 2016. *Trends in Global CO_2 Emissions: 2016 Report*. European Commission, Joint Research Centre (JRC), Directorate Energy, Transport & Climate; The Hague, N etherlands: PBL Netherlands Environmental Assessment Agency.

NOTES

1 One million cars and 20 million motorcycles at the end of 2010, an increase from 450,000 cars and 6 million motorcycles at the end of 2000.

2 For more information see UNFCCC's NDC Registry at https://www4.unfccc.int/sites/NDCStaging/Pages/All.aspx.

2. Assessment of Biofuel Deployment Context According to NDC Commitments and Recommendations for Biofuel Development Scenarios

2.1 Vietnam's Efforts and Achievements in Deploying Biofuels in Transportation

2.1.1 Existing policies to promote biofuels in Vietnam

In Vietnam, biofuels are defined as one type of renewable energy in accordance with Clause 1, Article 43 of Law No. 55/2014/QH13 on Environmental Protection dated June 23, 2014. Generally, national energy development strategies set a long-term target for the share of renewable energy in the total primary energy supply. In addition, the government of Vietnam approved "the National Energy Development Strategy to 2020, Vision to 2050" by Decision No. 1855/QĐ-TTg dated December 27, 2007; according to the strategy, the share of renewable energy will be 5 percent as of 2020. For the period from 2021 to 2030, the Political Bureau of Vietnam promulgated Resolution No. 55-NQ/TW on "Strategic Orientation for National Energy Development to 2030, Vision to 2045" in February 2020; according to the resolution, the share of renewable energy will reach 15 percent to 20 percent of the total primary energy supply as of 2030. It reveals that biofuels have been considered as one of the key policy options by the government of Vietnam. The fundamental biofuel policy direction was provided in the prime minister's Decision No. 177/2007/QĐ-TTg on November 20, 2007, and Decision No. 53/2012/QĐ-TTg on November 22, 2012. Following these decisions, the government of Vietnam issued policies and regulations in various aspects, such as feedstock supply, ethanol supply, biogasoline supply, and consumption. The outline of such policies and regulations is provided in the following sections.

2.1.1.1 Policies for biofuel production and supply

On November 20, 2007, the government of Vietnam promulgated Decision No. 177/2007/QĐ-TTg on "Approval of Project on Development of Biofuels to 2015, Vision to 2025." According to this decision, there are several targets in three main aspects, including: volume of ethanol and vegetable oils, volume of gasoline E5 and diesel B5, and ratio of E5 and B5 to total national demand for gasoline and diesel. Those targets are used for the government authorization of projects that contribute for the development of biofuels. The targets are summarized in Table 2.1.

TABLE 2.1. **Targets for Production of Ethanol, Gasoline E5, and Diesel B5 in Vietnam**

Target	Timeline		
	2010	2015	2025
Volume of ethanol & vegetable oils (thousand tons)	-	250	1,800
Volume of gasoline E5 and diesel B5 (thousand tons)	150	5,000	-
Ratio of E5 & B5 to total national demand for gasoline and diesel	0.4%	1%	5%

Source: Decision No. 177/2007/QĐ-TTg.

Additionally, the government of Vietnam issued Decision No. 2068/QĐ-TTg on "Approval of the Development Strategy for Renewable Energy of Vietnam to 2030, Vision to 2050" in November 2015. By 2050, the volume of biofuels is expected to reach 10.5 million tonnes of oil equivalent (TOE), meeting 25 percent of total fuel demand in the transport sector. It can be seen that Decision No. 177/2007/QĐ-TTg focuses on gasoline E5 and diesel B5 in particular, while Decision No. 2068/QĐ-TTg only mentions the target for biofuels in general.

TABLE 2.2. **Target for Biofuel Production in Vietnam**

Criteria	**Timeline**		
	2020	**2030**	**2050**
Volume of biofuels (thousand TOE)	800	3,700	10,500
Ratio of biofuels to total fuel demand in transport sector	5%	13%	25%

Source: Decision No. 2068/QĐ-TTg.

In 2012, the government of Vietnam issued Decision No. 53/2012/QĐ-TTg on "Roadmap for Biofuel Blending." According to Article 3 of this decision, four types of biofuels are commercialized, including gasoline (E5 and E10) and diesel (B5 and B10). On the one hand, road maps for selling gasoline E5 and E10 are mentioned. Specifically, gasoline E5 will be sold nationally from December 1, 2015, onward, while nationwide sales of gasoline E10 will take place from December 1, 2017, onward. On the other hand, the decision did not specify the road map for commercialization of diesel B5 and B10.

TABLE 2.3. **Road Map for Biogasoline Blending in Vietnam**

Type of Biofuel	**Applicability**	
	Timeline	**Area**
Gasoline E5	From December 1, 2014	5 centrally run cities: Hanoi, Ho Chi Minh City, Hai Phong, Da Nang, and Can Tho, and 2 provinces: Ba Ria-Vung Tau and Quang Ngai
	From December 1, 2015	Nationwide
Gasoline E10	From December 1, 2016	5 centrally-run cities: Hanoi, Ho Chi Minh City, Hai Phong, Da Nang, and Can Tho, and 2 provinces: Ba Ria-Vung Tau and Quang Ngai
	From December 1, 2017	Nationwide

Source: Decision No. 53/2012/QĐ-TTg.

Complying with Decision No. 53/2012/QĐ-TTg, biogasoline E5 RON 92 was sold from December 1, 2014, in seven cities and provinces, and its nationwide commercialization was started from December 1, 2015. To push the implementation of the biofuel road map, the government of Vietnam issued Directive No. 23/CT-TTg dated August 31, 2015, on "Reinforcing the Use, Blending and Distribution of Bio-gasoline Following Decision No. 53/2012/QĐ-TTg." According to the directive, gasoline traders must do the following tasks:

- Key gasoline traders (including gasoline exporters, importers, and producers) must accelerate the construction of blending systems and expand the network of retail stations for E5 gasoline. The target is that at least 50 percent of key traders' retail stations can sell E5 gasoline in five cities (Hanoi, Ho Chi Minh City, Hai Phong, Da Nang, and Can Tho) and two provinces (Quang Ngai and Ba Ria-Vung Tau) by November 30, 2015.
- Gasoline distributors, general agents, retail agents, and retail franchisers must expand the network of retail stations for E5 gasoline. The target is that at least 50 percent of distributors and agents' retail stations can sell E5 gasoline in five cities (Hanoi, Ho Chi Minh City, Hai Phong, Da Nang, and Can Tho and two provinces (Quang Ngai and Ba Ria-Vung Tau) by November 30, 2015.

It should be noted that both gasoline RON 92 and biogasoline E5 RON 92 existed before January 1, 2018. However, the government office of Vietnam issued Notification No. 255/TB-VPCP dated June 6, 2017. According to the notification, a business of gasoline RON 92 shall be banned from January 1, 2018. The government of Vietnam has allowed only biogasoline E5 RON 92 and gasoline RON 95 to be commercialized nationwide. Up to now, only gasoline E5 is available to customers, but there has been no commercialization of gasoline E10 as well as diesel B5 and B10.

2.1.1.2 Incentives to promote biofuels

Following Decision No. 177/2007/QĐ-TTg and Decision No. 53/2012/QD-TTg, public agencies of Vietnam formulated supporting policies for the promotion of biogasoline usage. These polciies can be summarized into four types: feedstock supply, ethanol supply, biogasoline production, and end users. Within the scope of this report, we present the incentives for ethanol and biofuel production only.

* **Investment incentives**

From 2015 to 2020, production of renewable energy, clean energy, is in the list of business lines that are eligible to receive investment incentives, according to Point b, Clause 1, Article 16 of Investment Law No. 67/2014/QH13 dated November 26, 2014 (referred to as the 2014 Investment Law). This regulation was retained when the National Assembly of Vietnam enacted Investment Law No. 61/2020/QH14 on June 17, 2020 (referred to as the 2020 Investment Law). The 2020 Investment Law came into effect on January 1, 2021.

Production of ethanol and biogasoline may benefit from investment incentives since ethanol and biogasoline are considered renewable or clean energy. According to Clause 1, Article 15 of the 2020 Investment Law, there are four types of investment incentives:

- Incentives for enterprise income tax
- Exemption from import tax on imported goods, raw materials, and supplies for production activities

- Incentives for land use levy, land use fee, and land use tax
- Shorter time frame of depreciation, leading to increase of deductible expenses when taxable income is calculated.

TABLE 2.4. **Investment Incentives for Production of Renewable Energy in Vietnam**

Types of Incentives	Timeline	
	From July 1, 2015, to the end of 2020a	From Janaury 1, 2021b
Enterprise income tax	Yes	Yes
Import tax	Yes	Yes
Land use levy, fee, and tax	Yes	Yes
Shorter time frame of depreciation cost	No	Yes

Source: a: Law No. 67/2014/QH13; b: Law No. 61/2020/QH14.

* **Enterprise Income Tax**

On June 19, 2013, the National Assembly of Vietnam enacted Law No. 32/2013/QH13 on "Amendments to Law on Enterprise Income Tax" (referred to as the 2013 Enterprise Income Tax Law). According to the law, the enterprise income tax rate is generally 22 percent, except for particular lines of business. According to Clause 1, Article 13 of the law, the tax rate of 10 percent for 15 years applies to the revenues of enterprises from the production of renewable energy, clean energy, and energy from waste destruction. Hence, ethanol and biogasoline producers may benefit from this regulation.

* **Import tax on machinery and equipment**

On April 6, 2016, the National Assembly of Vietnam enacted Law No. 107/2016/QH13 on "Import Tax and Export Tax." According to Point a, Clause 19, Article 16 of the law, imported machinery, equipment, equipment, tools, and supplies used to produce renewable energy are exempt from import tax if such imported objects cannot be domestically produced. Following this law, the government of Vietnam promulgated Decree No. 134/2016/NĐ-CP dated September 1, 2016, on "Guidelines for the Law on Export and Import Tax." According to Article 25 and Article 50 of this decree, the Ministry of Planning and Investment (MPI) shall publish a list of goods that can be domestically produced, while the MONRE is responsible for the issuance of a list of criteria for identification of imported machinery, equipment, vehicles, tools, and supplies used for environmental protection (including production of renewable energy).

Imported machinery, equipment, vehicles, tools, and supplies for the production of ethanol and biogasoline may benefit from the regulation on import tax if producers can meet the two abovementioned conditions. For the first condition, the MPI issued Circular No. 01/2018/TT-BKHĐT dated March 30, 2018, on "The Lists of Machinery, Equipment, Replacement Parts, Special-Purpose Vehicles, Raw Materials, Supplies, and Semi-Products that Manufacturable Domestically." Based on this circular, biofuel suppliers can clarify whether or not imported goods cannot be domestically produced. However, there has been a lack of legal basis for the second condition since the MONRE has not promulgated the list of imported machinery, equipment, vehicles, tools, and supplies used for environmental protection.

* Export and import tariff for cassavas

Dried cassava chips are the main input in the process of ethanol production in Vietnam. Hence, export and import tariffs on cassavas may have a significant impact on the feedstock supply for ethanol production. From 2016 to now, both fresh and dried cassavas have a special preferential export tax rate of 0 percent and preferential import tax rate of 3 percent in accordance with Decree No. 57/2020/NĐ-CP of May 25, 2020, Decree No. 125/2017/NĐ-CP of November 16, 2017, and Decree No. 122/2016/NĐ-CP of September 1, 2016.

TABLE 2.5. **Export and Import Tariffs on Cassavas**

Fresh and Dried Cassavas	Timeline		
	September 1, 2016, to end of 2017a	January 1, 2018, to end of 2019b	From January 1, 2020c
Export tax rate	0%	0%	0%
Import tax rate	3%	3%	3%

Source: a: Decree No. 122/2016/NĐ-CP; b: Decree No. 125/2017/NĐ-CP; c: Decree No. 57/2020/NĐ-CP.

* Import tax on ethanol

Ethanol is the key input for blending biogasoline. According to Notification No. 255/TB-VPCP dated June 6, 2017, the Ministry fo Finance (MOF) was assigned to the study and promulgation of import tax policy for ethanol to prevent the monopoly of ethanol supply. The import tax rate for ethanol reduced from 20 percent in 2016 to 15 percent in 2020.

Table 2.6. Import Tax on Ethanol

Types of Ethanol	Timeline		
	January 1, 2016, to end of 2017a	January 1, 2018, to end of 2019b	From January 1, 2020c
Ethanol 99% (Code 2207.20.11)	20%	17%	15%
Others (Code 2207.20.19)	20%	20%	15%

Source: a: Decree No. 122/2016/NĐ-CP and Circular No. 182/2015/TT-BTC; b: Decree No. 125/2017/NĐ-CP; c: Decree No. 57/2020/NĐ-CP.

* Taxes on biogasoline

Three types of taxes are levied on biogasoline: value added tax (VAT), Special Consumption Tax (SCT), and Environmental Protection Tax (EPT).

TABLE 2.7. **Taxes on Biogasoline**

Type of Taxes	Biogasoline (E5 RON92)	Gasoline (RON95)
VAT taxa	10%	10%
SCT taxb	8%	10%
EPT taxc	3,800 VND/liter	4,000 VND/liter

Source: a: Consolidated Document No. 01/VBHN-VPQH; b: Law No. 70/2014/QH13; c: Decree No. 67/2011/NĐ-CP and Resolution No. 579/2018/UBTVQH14.

According to Consolidated Document No. 01/VBHN-VPQH on VAT Tax Law, VAT tax rates of 0 percent or 5 percent do not apply to ethanol and biogasoline. Both biogasoline (E5 RON92) and conventional gasoline (RON95) have the same VAT tax rates of 10 percent. In other words, there is no difference in VAT tax policy between biogasoline and conventional gasoline.

On November 26, 2014, the National Assembly of Vietnam promulgated Law No. 70/2014/QH13 on Amendment of Several Articles of Law on Special Consumption Tax (SCT). This law took effect on January 1, 2016. Unlike the previous law on SCT Tax (Law No. 27/2008/QH12 on November 14, 2008), the biogasoline tax rate (i.e., gasoline E5 and E10) shall be lower than conventional gasoline. Specifically, biogasoline (E5 RON92) will have a tax rate of 8 percent, while a tax of 10 percent is levied on conventional gasoline (RON95).

In 2010, the National Assembly of Vietnam enacted Law No. 57/2010/QH12 on EPT. In accordance with Article 8 of the law, the tax rate of gasoline shall be in a range of D1,000 and D4,000, while a tax rate of D500 to D2,000 shall be levied on diesel oil. Following the law, the government of Vietnam promulgated Decree No. 67/2011/NĐ-CP dated August 8, 2011, on "Guidelines for Implementation of Some Article of the Law on ETP tax." As per Article 3 of the decree, taxable fuels are only based on the amount of gasoline or oils if a mixed fuel contains biofuel and gasoline (or oils). Currently, the tax rate of EPT is regulated by Resolution No. 579/2018/UBTVQH14 of the Standing Committee of the National Assembly. The resolution took effect on January 1, 2019. According to Article 1 of the resolution, a tax rate of D4,000 is levied on one liter of gasoline (except for ethanol), and diesel oil has a tax rate of D2,000.

2.1.2 Contributions to GHG emissions mitigation

2.1.2.1 Ethanol supply and consumption

Currently, the supply of ethanol for blending biogasoline E5 RON92 is primarily from two ethanol plants of the Tung Lam Co. Ltd. with a total maximum capacity of 192,000 m^3 per year. One ethanol plant is located in Dong Nai province in the Southeast region, and the other is in Quang Nam province in the South Central Coast region. The amount of ethanol produced by these two plants is enough to blend 3.84 million m^3 (mcm) (or 2.688 million tons, conversion rate: 1 m^3 = 0.7 ton) of E5 RON92 biogasoline.

Additionally, there are two other ethanol plants in Quang Ngai and Binh Phuoc provinces. The maximum capacity of each plant is 100,000 m^3 per year. However, the Binh Phuoc plant is temporarily out of service and the Quang Nai plant has discontinuous service due to financial loss. If four ethanol plants are fully in operation, the maximum capacity is 400,000 m^3 per year (or 400 million liters per year).

TABLE 2.8. **Existing Ethanol Plants in Vietnam**

No.	Name	Location	Maximum Capacity	Current Status
1	Tung Lam ethanol plant	Dong Nai province (Southeast region)	72,000 m3/year (or 72 million liters/year)	In operation
2	Tung Lam ethanol plant	Quang Nam province (South Central Coast region)	120,000 m3/year (or 120 million liters/year)	In operation
3	Binh Phuoc ethanol plant	Binh Phuoc province (Southeast region)	100,000 m3/year (or 100 million liters/year)	Temporarily closed
4	Quang Ngai ethanol plant	Quang Ngai province (South Central Coast region)	100,000 m3/year (or 100 million liters/year)	Discontinuous operation

Sources: MOIT 2017 and study team.

Note: 1 m^3 = 1,000 liters.

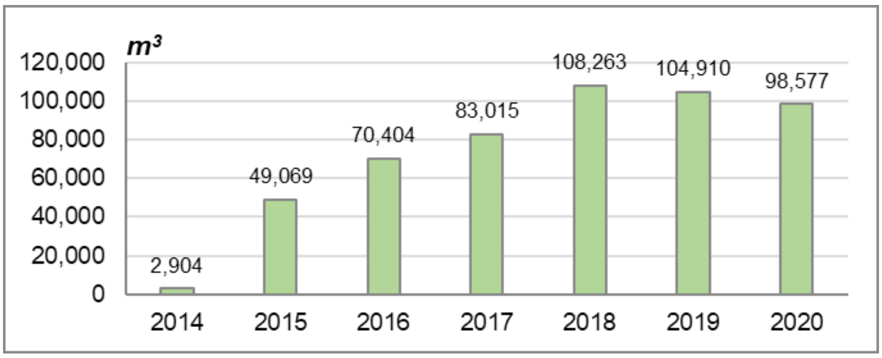
TABLE 2.9. **Supply of Ethanol for Biofuel Blending**

Supply Resource	Unit	2016	2017	2018	2019
Domestic supply	m3	23,970	140,857	241,495	262,382
Import	m3	75	54	15	162
Export	m3	414	760	527	5,067

Source: Institute of Energy.

Based on a World Bank survey of key traders of biogasoline, the annual amount of ethanol used to blend biogasoline is estimated for the period from 2014 to 2020. Specifically, the demand for ethanol was only 2,903 m^3 in 2014, and it peaked at 108,203 m^3 in 2018. The demand for ethanol used for blending biogasoline dreased in the period from 2019 to 2020. Note that biogasoline was sold only in seven cities from December 1, 2014. The national sales of biogasoline were carried out from December 1, 2015, in accordance with Decision No. 53/2012/QĐ-TTg (or Roadmap 53).

FIGURE 2.1. **Amount of Ethanol Used to Blend Biogasoline**

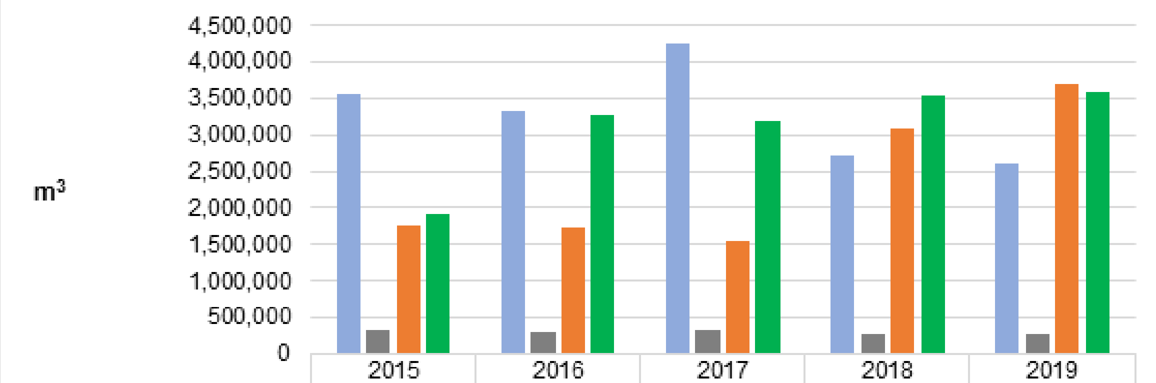


Source: Study team.

2.1.2.2 Biogasoline supply and consumption

E5 RON92 biogasoline is a blend of conventional RON92 gasoline (also known as A92 gasoline) and ethanol. The supply of RON92 gasoline is from imports or domestic oil refinery plants. According to the Vietnam Petroleum Institute's data, the amount of imported gasoline decreased from 3.5 mcm in 2015 to 2.6 mcm in 2019. In the same period, the amount of gasoline from domestic oil refinery plants doubled from 3.6 mcm to 7.2 mcm. From 2015 to 2017, the amount of domestically produced A92 gasoline was considerably more than A95 gasoline. However, the amount of domestically produced A95 gasoline sharply increased in the period from 2018 to 2019. This may infer the upward and downward trends of E5 RON92 gasoline in the same periods.

FIGURE 2.2. **Mineral Gasoline Supply in Vietnam**

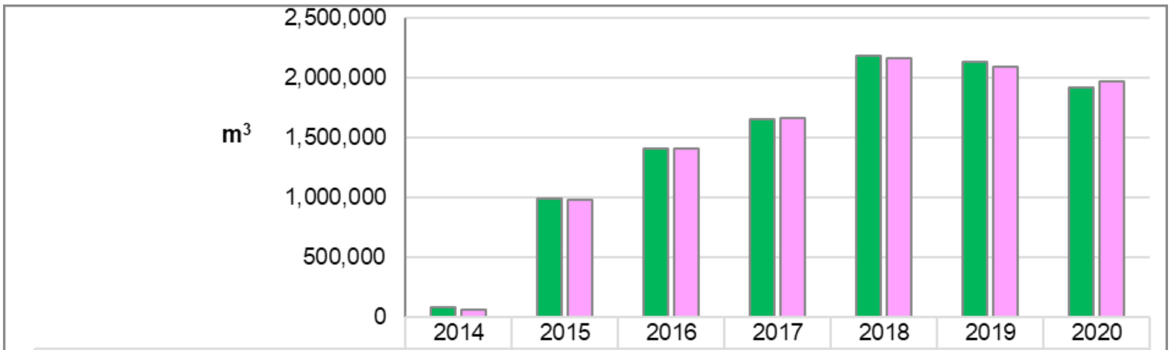


	2015	2016	2017	2018	2019
Imported gasoline	3,574,799	3,316,801	4,239,367	2,714,667	2,619,201
Exported gasoline	323,560	286,351	336,285	277,333	268,884
Domestic A95 gasoline	1,752,000	1,720,000	1,546,667	3,082,000	3,693,333
Domestic A92 gasoline	1,910,733	3,274,667	3,200,000	3,536,667	3,600,000

Sources: Vietnam Petroleum Institute and Vietnam Customs.

The annual volume of actual biogasoline production had an increasing trend between 2014 and 2018, but it experienced a decline in the period from 2018 to 2020. This may infer an upward and downward trend of biogasoline demand in the same period. Specifically, the production of biogasoline increased from 981,380 m^3 in 2014 to 2,165,256 m^3 in 2018. Then, it went down to 1,971,530 m^3 in 2020. As per the record of key traders, the amount of biogasoline sold in the domestic market is approximately equal to that of production. It is noted that key traders may sell biogasoline to various clients, such as other gasoline traders, retailers, and end users. Hence, it is not easy to distinguish the biogasoline consumption of end users from that of other clients.

FIGURE 2.3. **Volume of Biogasoline Production in Vietnam**

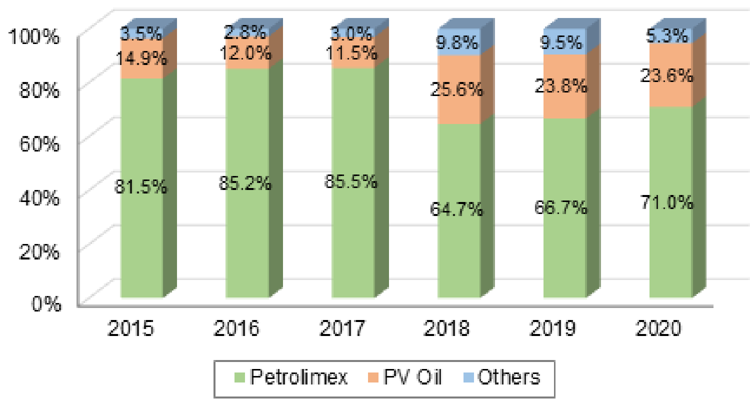


	2014	2015	2016	2017	2018	2019	2020
Amount of biogasoline sales to domestic market	74,750	992,267	1,411,767	1,651,011	2,189,108	2,134,573	1,915,959
Amount of biogasoline production (actual)	58,077	981,380	1,408,084	1,660,293	2,165,256	2,098,191	1,971,530

Source: 2021 World Bank survey of key biogasoline traders in Vietnam.

According to an average annual amount of biogasoline production, Petrolimex is the biggest gasoline supplier (75.8 percent), followed by PV Oil (18.6 percent) and the others (6 percent). Particularly, the share of Petrolimex had a slight increase of 4 percent from 2015 to 2017, then a significant decrease of 14 percent was recorded from 2017 to 2020. At the same time, the share of PV Oil experienced a decline from 14.9 percent in 2015 to 11.5 percent in 2017, but its share was more than 23 percent on average in the periods from 2018 to 2020.

FIGURE 2.4. **Share of Actual Biogasoline Production by Key Traders in Vietnam**

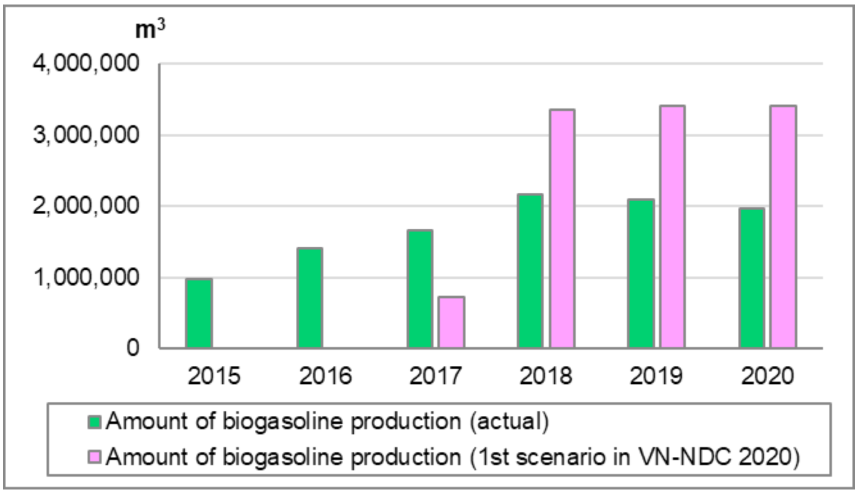


Source: Study team.

For an actual share of E5 gasoline, data from the Ministry of Industry and Trade (MOIT) will be used in this study (MOIT 2017, 2018, 2019). The result indicated that an average annual share was 24 percent between 2016 and 2019. Specifically, the actual share increased from 8 percent in 2016 to 42 percent in 2018, and then it declined to 38 percent in 2019. According to a scenario with only domestic resources of the updated NDC of Vietnam in July 2020 (VN-NDC 2020), it is hypothesized that an average annual amount of ethanol used for the production of biogasoline E5 is 145,000 m^3

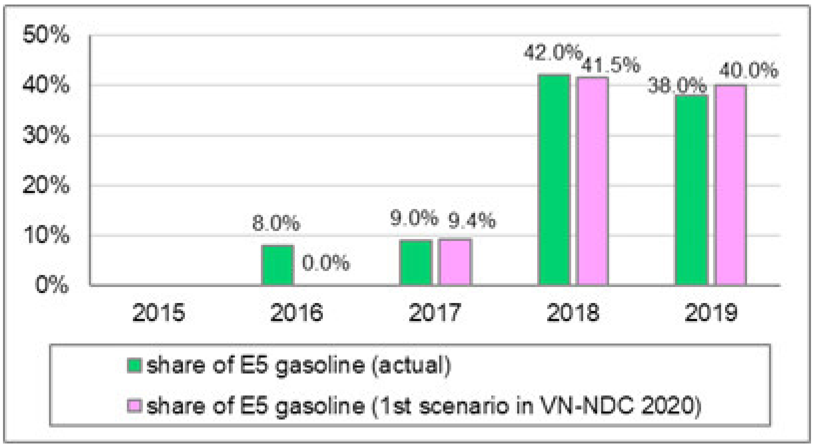
(first scenario of VN-NDC 2020). It can be seen that the implementation of biofuels has reached the NDC target for the period from 2015 to 2019. As illustrated in Figure 2.6, the actual consumption of E5 gasoline was 42 percent in 2018, but this rate decreased to 38 percent in 2019.

FIGURE 2.5. **Amount of Biogasoline Production: Actual versus First Scenario in VN-NDC 2020**



Source: Study team.

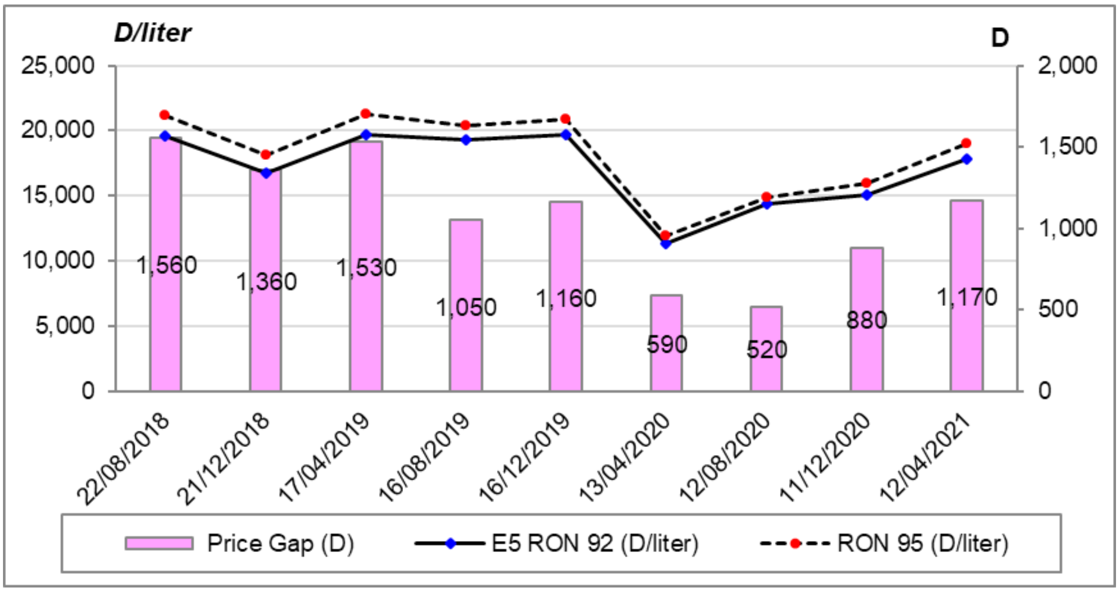
FIGURE 2.6. **Ratio of E5 Gasoline Consumption: Actual versus First Scenario in VN-NDC 2020**



Sources: MOIT 2017, 2018, and 2019 and study team.

The price of E5 RON 92 seems to not be attractive to price-sensitive consumers. Generally, there is not a significant gap between biogasoline and conventional prices. From August 2018 to April 2021, the price gap between gasoline E5 RON92 and gasoline RON95 was about D1,000 on average. The price gap peaked at D1,506 in August 2018, and it declined to the lowest point at D520 in August 2020. Then, the price gap experienced an increase of D600 from August 2020 to April 2021.

FIGURE 2.7. **Gasoline Prices in Vietnam: E5 RON92 versus RON95**



Source: PV Oil.

2.2 Analysis of the Trend of Biofuels in the Period from 2021 to 2030

2.2.1 International experience with biofuel promotion

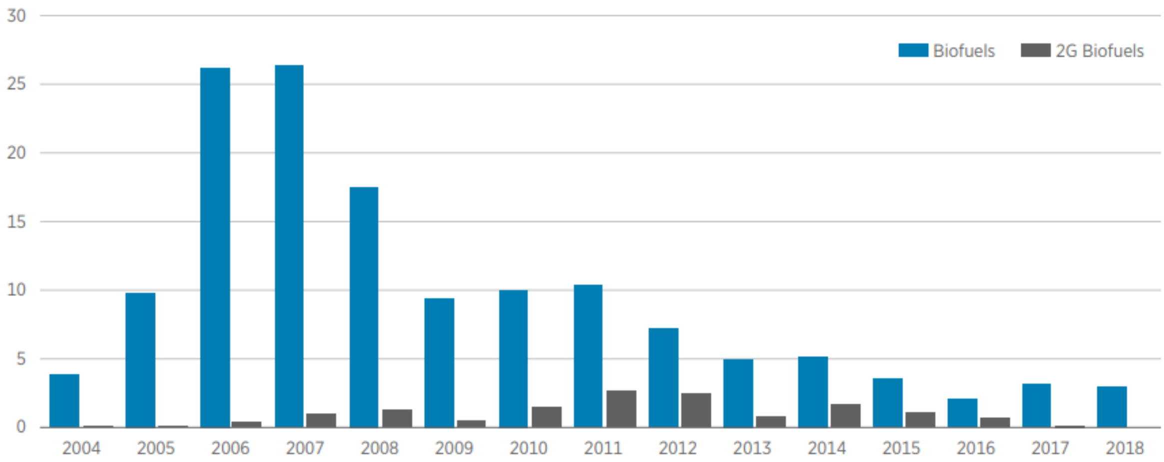
Biofuels have a long history in transport, energy, and climate policies in Europe, Brazil, and North America. Governments have created supporting policies for biofuels driven by various objectives relating to the fight against climate change, energy security, oil import reduction, and agricultural and rural development.

Managing agricultural overproduction and sustaining prices for key crops in Europe and the United States became a growing concern in the 1980s and 1990s, to which ethanol blended with gasoline provided one solution. Pursuance of a modest share of ethanol in gasoline was not against the oil industry's interest as it provided a solution to knock resistance replacing lead when countries started banning, one by one, the use of lead in gasoline for environmental and health reasons.

Over the last two decades, climate concerns have become an increasingly strong motivation for policies promoting biofuels. This has resulted in growing support for biofuels and the production of biodiesel and fuel ethanol. These policies triggered a substantial investment boom, which peaked in 2007 when several sustainability concerns related to the impacts of biofuels on food security, food and feed prices, and direct and indirect land use became an integral part of the international climate and energy debate.

The food-versus-fuel debate, particularly, mobilized the scientific community, governments, and nongovernmental organization (NGOs) and led to studies on the carbon intensity of various types of liquid biofuels. Studies now consider the life cycle emissions of the supply chains and emissions due to land use change (LUC) and indirect land use change (ILUC) caused by growing feedstock for biofuels. Consequently, regulators in the largest markets, particularly the United States and the European Union (EU), reset their biofuel targets, blending mandates and support policies considering fuel distinctions by feedstock and associated carbon intensities.

FIGURE 2.8. **Annual Global Investments in Biofuels**



Source: IRENA 2019.

Note: 2G data for 2018 not available. Data are in US$, billion.

In the view of life cycle assessment, biofuels also generate GHGs from the raw feedstock production to transport, conversion to biofuels distribution, and end use (Sikarwar et al. 2017). Based on this approach, Sikarwar et al. (2017) compared GHG emissions by gasoline and biofuels produced from a variety of feedstocks. Compared to gasoline, biofuels produced from cellulosic and sugarcane have the most significant potential, cutting GHG emissions by 80 percent to 90 percent. However, corn-based biofuels can only cut GHG emissions by 20 percent. This indicates that GHG emissions from biofuels vary by type of feedstock. Hence, it is important to select fewer GHG-emitting feedstocks for the production of biofuels.

Support policies for biofuels are often driven by energy security concerns, coupled with the desire to sustain the agricultural sector and revitalize the rural economy. More recently, the reduction of CO_2 emissions from the transport sector has become an essential driver for biofuel development, particularly in countries belonging to the Organisation for Economic Co-operation and Development (OECD). One of the most common support measures is a blending mandate, which defines the proportion of biofuel that must be used in (road-) transport fuel, often combined with other measures such as tax incentives. More than 50 countries, including several non-OECD countries, have adopted blending targets or mandates, and several more have announced biofuel quotas for future years.

TABLE 2.10. **Biofuel Blending Targets and Mandates**

Country/Region	Current Mandate/Target	Future Mandate/Target	Current Status [(mandate (M)/ target (T)]
Argentina	E5, B7	n.a.	M
Australia	E4, B2	E6 (2011), B5 (2012)	M
Bolivia	E10, B2.5	B20 (2015)	T
Brazil	E20–25, B5	n.a	M
Canada	E5–E8, B2–B3	B2 (nationwide)	M
Chile	E5, B5	n.a.	T
China	E10	n.a.	M
Colombia	E10, B10	B20	M
Costa Rica	E7, B20	n.a	M
European Union	5.75% biofuels*	10% renewable energy in transport**	T
India	E5	E20, B20	M
Indonesia	E3, B2.5	E15, B20 (2025)	M
Jamaica	E10	Renewable energy in transport: 11% (2012); 12.5% (2015); 20% (2030)	M
Japan	500 Ml/y (oil equivalent)	800 Ml/y (2018)	T
Kenya	E10	n.a.	M
Malaysia	B5	n.a.	M
Mexico	E2	E2	M
Mozambique	n.a.	E10, B5	n.a
Norway	3.5% biofuels	5% in 2011; possible alignment with EU mandate	M
Nigeria	E10	n.a.	T
Paraguay	E24, B1	n.a.	M
Peru	E7.8, B2	B5	M
Philippines	E5, B2	B5, E10	M
Republic of Korea	B2	B2.5, B3	M
South Africa	n.a.	2% (2013)	n.a.
Taiwan	B2, E3	n.a.	M
Thailand	B3	3 Ml/d ethanol, B5 (2011); 9 Ml/d ethanol (2017)	M
Uruquay	B2	E5 (2015), B5 (2012)	M
United States	48 billion liters of which 0.02 Gl. cellulosic-ethanol	136 billion liters, of which 60 Gl. cellulosic-ethanol (2022)	M
Venezuela	E10	n.a.	T
Zambia	n.a.	E5, B10	n.a.

B = biodiesel (B2 = 2% biodiesel blend); E = ethanol (E2 = 2% ethanol blend); Ml/d = million liters per day. *Currently, each member state has set up different targets and mandates. **Lignocellulosic-biofuels, as well as biofuels made from waste and residue, count twice and renewable electricity 2.5 times toward the target.

Source: IEA 2011.

Next to mandates, tax incentives have proven effective even as the sole regulatory measure if the incentive level is strong enough. Tax cuts, rebates, and credits are ways to improve the price competitiveness of renewable fuels. Fuel and/or carbon taxes imposed on fossil fuels can be used for the same purpose by making fossil fuel alternatives more expensive. A universal and revenue-neutral carbon tax is often seen as the most advanced and fair tax measure to promote the deployment of low-carbon fuels. It is completely fuel technology neutral and not fiscal in the sense that tax revenues are returned to the taxpayers. According to a World Bank report on the state and trends of carbon pricing (World Bank 2018), some national jurisdictions had carbon taxes on fossil fuels. For instance, Finland's carbon tax rate for fossil fuels rose from €58/tCO2e (US$72/tCO2e) to €62/tCO2e (US$77/tCO2e) on January 1, 2018.

2.2.2 Orientation for development of biofuel supply

2.2.2.1 Target for biogasoline and biodiesel

Up to now, there are three official documents regarding the target for the share of biogasoline, including: Biofuel Scheme No. 177, Renewable Energy Strategy No. 2068, and VN-NDC 2020. Firstly, a target of 5 percent by 2025 is mentioned in Biofuel Scheme No. 177. However, this target seems to be underestimated since the actual share of biogasoline is larger than 5 percent in the period from 2015 to 2020. Secondly, Renewable Energy Strategy No. 2068 set the targets of 13 percent in 2030 and 25 percent in 2050. In comparison with the actual shares of biogasoline in the period from 2015 to 2019, these targets appear low. Finally, there are two options of the target for the share of biogasoline in the period from 2021 to 2030, including: 2.9 mcm of biogasoline per year, or 40 percent per year.

TABLE 2.11. **Approved Targets for the Share of Biogasoline in 2021–30**

Legal Documents	Share of Biogasoline (%)				
	2025	**2030**	**2040**	**2045**	**2050**
Decision No. 177/2007/QĐ-TTg (2007)	5%	-	-	-	-
Decision No. 2068/QĐ-TTg (2015)	-	13%	-	-	25%
VN-NDC 2020 (1st Scenario)	2.9 mcm of E5 gasoline		-	-	-

Source: Study team.

Remarkably, Vietnam Green Growth Strategy (VGGS) from 2021 through 2030, vision to 2045 (VGGS 2021–2030) was approved by Decision No 1658/QĐ-TTg dated October 1, 2021. According to the report of VGGS 2021–30, the promotion of biofuel for road transport vehicles is one of the mitigation measures. Tentatively, the target for the share of biogasoline to the total amount of gasoline sold is 40 percent in the period from 2019 to 2024, 30 percent in 2030, and 45 percent in 2050.

2.2.2.2 Road map for blending

* **Blend mandate**

Up to now, only the blend mandate for gasoline RON92 has been implemented in accordance with Notification No. 255/TB-VPCP of the government office in 2017. There are no legal documents regarding a blend mandate for gasoline RON95. The government of Vietnam is the approval agency for this policy. The latest relevant document is Renewable Energy Strategy No. 2068 (approved by the government of Vietnam in 2015). According to this strategy, the development orientation to 2030 for biofuels is that biogasoline and biodiesel shall cover a part of the total national demand for gasoline and diesel. In other words, there is no orientation that the share of biogasoline and biodiesel shall be 100 percent in the transport sector. Additionally, the blend mandate for gasoline RON 95 and diesel has not been mentioned in the report of VGGS 2021–30. In summary, there is uncertainty about implementing a blend mandate policy for all types of gasoline and diesel in the period from 2021 to 2025. Therefore, the possible scenario is that there will be no blend mandate for diesel, only the current blend mandate for gasoline shall be continuously carried out. This scenario is consistent with that of VGGS 2021–2030.

* **Blending rates for gasoline and diesel**

Existing policy directions for the ethanol blend rate are provided in two legal documents: Biofuel Scheme No. 177 and Decision No. 53/2012/QĐ-TTg (referred to as Biofuel Roadmap No. 53). On the one hand, only the ethanol blend rate of 5 percent for both gasoline and diesel (i.e., gasoline E5 and diesel B5) is mentioned in the Biofuel Scheme No. 177. On the other hand, 5 percent and 10 percent rates are shown in Biofuel Roadmap No. 53. However, only the road map for implementation of gasoline E5 and E10 is determined. While gasoline E5 is commercialized, gasoline E10 is not yet available in the market.

TABLE 2.12. **Approved Blending Rates**

Legal Documents	Blending Rate	Timeline
Decision No. 177/2007/QĐ-TTg	5%	• Gasoline E5: from 2010 • Diesel B5: from 2010
Decision No. 53/2012/QĐ-TTg	5% & 10%	• Gasoline E5: from 1/12/2014 • Gasoline E10: from 1/12/2016 • Diesel B5 & B10: undetermined

Source: Study team.

According to the Draft QCVN 1:2020/BHKCN on National Technical Regulations on gasoline, diesel, and biofuels, there are limits for technical criteria related to safety, health, and environment. In addition, this regulation provides quality management requirements for gasoline, diesel fuel, and biofuels, including:

- Unleaded gasoline, E5 gasoline, E10 gasoline
- Diesel fuel, B5 diesel fuel
- Biofuels: unmodified fuel ethanol, denatured fuel ethanol, and B100-based biodiesel.

According to the report of VGGS 2021–2030, a different scenario for biofuel development was made. Specifically, the assumption is that gasoline E5 will be continuously sold from 2019 to 2024, then it will be replaced by gasoline E10 from 2025. Additionally, it is assumed that there will be no biodiesel. It can be seen that, in the period from 2021 to 2030, the orientation policy on biofuel blend rate will still focus on E5 and E10 gasoline.

2.2.2.3 Applicability of biofuel to other transport subsectors

Currently, biofuels are only promoted in the road transport subsector. In other transport subsectors (e.g., railway and inland waterway), the use of biofuels has not as yet been prioritized. The existing policy direction for the use of ethanol in the transport subsector is provided in Renewable Energy Strategy No. 2068. In cooperation with the MOIT, the MOT has been assigned to develop scientific research and policies to promote the use of biofuels for private vehicles, public transport, freight transport, and aviation transport.

According to VGGS 2021–2030, biofuels are only applicable to the road transport subsector, and there have been no specific orientations for the application of biofuels to other transport subsectors. Additionally, the MOT promulgated Decision No. 452/QĐ-BGTVT dated March 24, 2021, on "Action Plan of MOT for Climate Change Adaptation, Reinforcement of Resource Management and Environmental Protection in the Period of 2021–2025." According to the action plan, there are no specific orientations for the use of biofuels in the transport subsectors. With respect to aviation transport, the MOT issued Decision No. 4206/QĐ-BGTVT dated December 28, 2016, on "Action Plan for Reduction of CO2 Emission from Civil Aviation Activity in the Period of 2016-2020." According to the decision, the MOT only plans to research alternative fuels for aviation transport activities in Vietnam. Therefore, the moderate scenario is that biofuels are only applicable to the road transport subsector. This scenario is consistent with that of VGGS 2021–2030.

2.2.2.4 Barriers for biogasoline producers

Five biogasoline producers participated in the interviews, including: Petrolimex, PV Oil, Saigon Petro, Petimex, and Vietnam Oil and Gas Group (PVN). PV Oil is a subsidiary of PVN. The feedback from these producers on the challenges they face and supportive policies is summarized as follows:

- First, the majority of biogasoline producers indicated issues of feedstock availability and price. Regarding feedstock availability, PV Oil and PVN had a common comment on the lack of a feedstock area plan for ethanol production. PVN clarified that "*Existing feedstock for the production of ethanol are food crops or industrial crops (e.g., cassava, sugarcane…), so the sector of ethanol production is competing with other sectors (e.g., production of flour, sugar, and animal feed) for feedstock*." Additionally, Saigon Petro had a comment on the supply of ethanol 100 percent (E100). According to Saigon Petro, the domestic supply of E100 sometimes did not meet the demand. With respect to feedstock price, PV Oil and PVN were concerned about the instability of inputs for the production of biogasoline. Specifically, PVN pointed out that biogasoline will not compete with conventional gasoline when the price of conventional gasoline is significantly decreased. On the other hand, Saigon Petro noted that the cost of imported E100 is often lower than that of E100 from domestic supply.

- Second, most ethanol producers did not have a concern about conversion technology and car technology. On this question, only Petemix answered "Yes," but no specific comment was made.

- Third, Petrolimex and PV Oil said they faced no barriers in the following aspects: financial; infrastructure for blending, transport, storage, and retailing; and laws and regulations. Petrolimex and PV Oil are the two biggest suppliers of both biogasoline and conventional gasoline in Vietnam. However, the rest of the interviewees had comments on those barriers. Regarding financial barriers, Saigon Petro said that tax policies for biogasoline are insufficient compared to conventional gasoline. PVN noted the strong competition between fossil fuels and biofuels due to the low price of pure oil. On infrastructure, both Saigon Petro and PVN mentioned the investment costs of the blending and storage systems for biogasoline. Regarding laws and regulations, Saigon Petro recommended an ethanol blend mandate for all types of gasoline. Additionally, PVN further clarified that "*Existing blend mandate is only applicable to gasoline RON 92. And existing policies for the price of biogasoline is not enough, so consumers still prefer conventional gasoline.*"

- Finally, the majority of biogasoline producers indicated the issues of customer demand and price of biogasoline. PVN and Saigon Petro stated that the price gap between biogasoline and conventional gasoline is not large enough. Biogasoline is only a little cheaper than conventional gasoline, so customers still prefer to use conventional gasoline.

TABLE 2.13. **Barriers Facing Ethanol Producers in Vietnam**

No.	Barriers	Biogasoline Producers				
		Petrolimex	PV Oil	Saigon Petro	Petimex	PVN
1	Feedstock availability	Yes	Yes	Yes	Yes	Yes
2	Feedstock price	Yes	Yes	Yes	Yes	No
3	Conversion technology	No	No	No	Yes	No
4	Car technology (engine)	No	No	No	No	No
5	Financial barriers (e.g., big investment cost, low interest)	No	No	Yes	Yes	Yes
6	Infrastructure for blending, transport, storage, and retailing	No	No	Yes	Yes	Yes
7	Laws and regulations (e.g., lack of blend mandate for biogasoline)	No	No	Yes	Yes	Yes
8	Customer demand	No	Yes	No	Yes	Yes
9	Price of biogasoline	Yes	No	Yes	Yes	Yes
10	Others, please specify	No	No	No	No	No

Source: Study team.

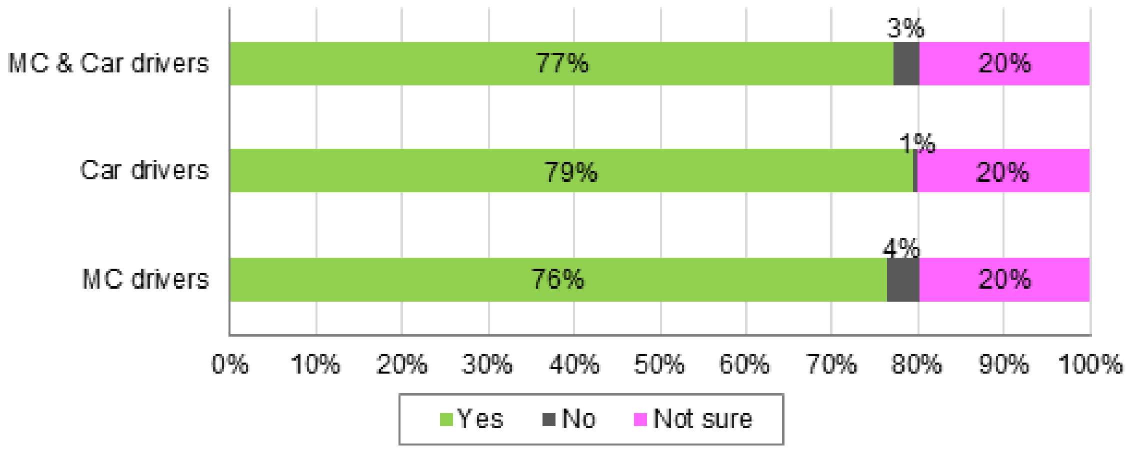
2.2.3 Biofuel demand

In order to analyze the demand for biofuel, end users (i.e., motorcycle and car drivers) were interviewed in Hanoi. In total, there were 600 respondents, including 450 motorcycle riders and 150 car drivers. In the second part of the questionnaire, respondents were asked about current fuel consumption as well as their views on the usage of biogasoline and supportive policies. The interview results are summarized in the subsequent subsections.

2.2.3.1 Current refueling behavior

First, respondents were asked whether they are aware of the availability of gasoline E5 RON92 at a gas station where they often refuel. There were three answer options: "Yes," "No," and "Not sure." Seventy-seven percent of motorcycle and car drivers were aware of the availability of gasoline E5 RON 92. Only 3 percent of respondents answered "No." Remarkably, 20 percent of interviewees were unsure whether gasoline E5 RON92 is available at a gas station where they often refuel.

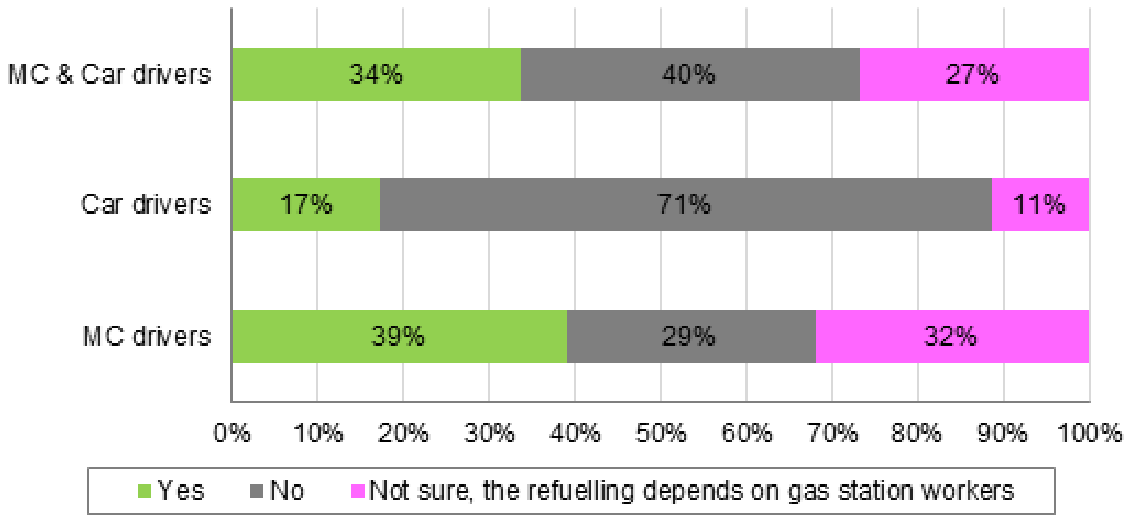
FIGURE 2.9. **Awareness of the Availability of Gasoline E5 RON92**



Source: Study team.

Second, the interviewees were asked whether they buy gasoline E5 RON 92 when it is available at gas stations. There were three answer options: "Yes," "No," and "Not sure." The result indicates significant difference in refueling behavior of motorcycle and car drivers. Specifically, 71 percent of car drivers do not use gasoline E5 RON 92, while only 29 percent of motorcycle drivers responded "No." However, more motorcycle drivers are unsure whether they used gasoline E5 RON 92 compared to car drivers. Overall, 34 percent of motorcycle and car drivers bought gasoline E5 RON 92 when refueling, but 67 percent said "No" or "Not sure."

FIGURE 2.10. **Usage of Gasoline E5 RON92 When Refueling**

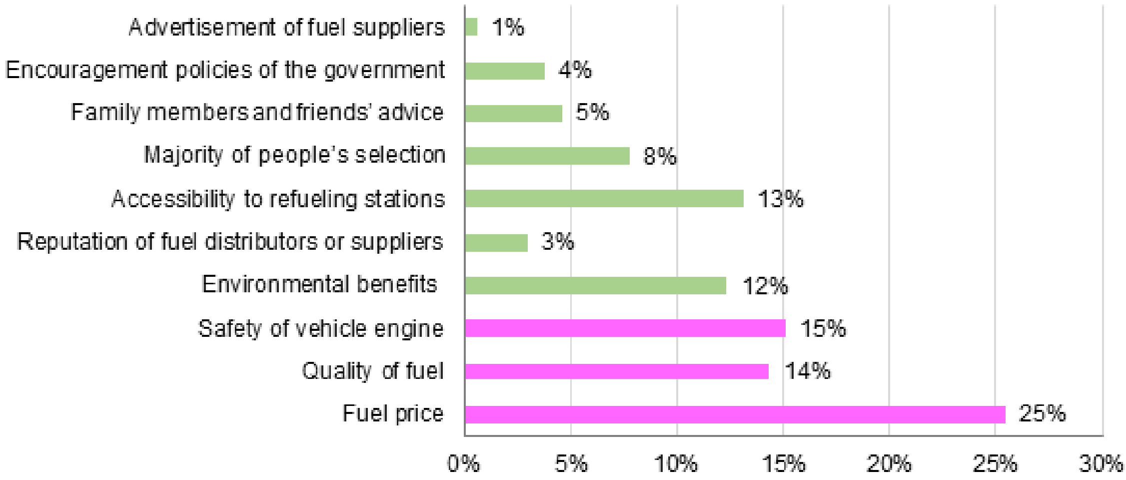


Source: Study team.

2.2.3.2 Awareness of biogasoline

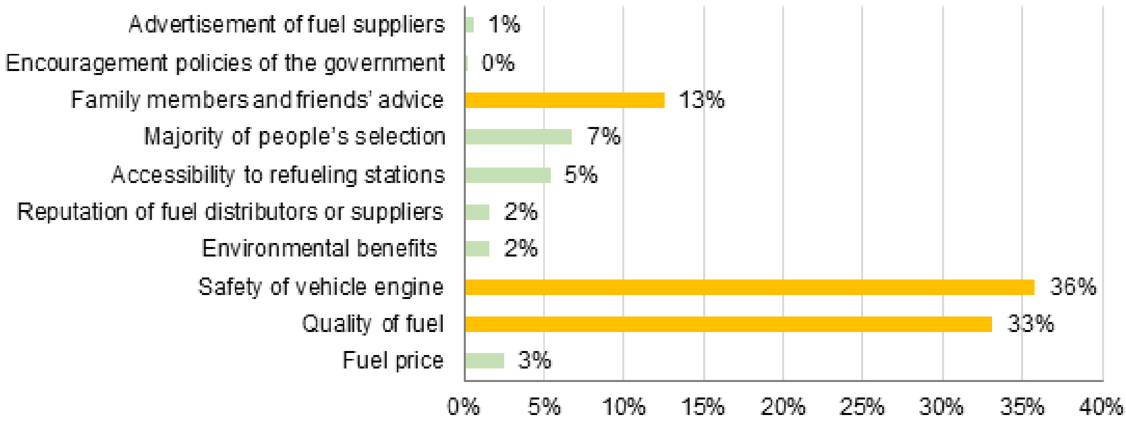
Interviewees were asked for the main reasons why they "used" or "did not use" gasoline E5 RON92 when they refuel. There is a list of 10 reasons (see figure below). Interviewees could give multiple answers, but there were a maximum of three options out of 10 reasons. For the main reasons why people chose biogasoline, the result indicates that fuel price is the most selected reason (accounting for 25 percent of total choice), followed by the safety of vehicle engine (15 percent) and fuel quality (14 percent). This implies that more supportive policies for the price of biogasoline may lead to an increase in biogasoline consumption. Among the main reasons why people did not use such biogasoline, the three most selected items are safety of vehicle engine (36 percent), fuel quality (33 percent), and the advice of family members or friends (13 percent). It seems that motorcycle and car drivers are concerned about the quality of biogasoline E5 RON92. They believe it may harm their vehicle engines. Such a belief is one of the barriers to the development of the biofuel market in Vietnam. The government should have in place more policies to raise people's awareness about the benefits of biogasoline.

FIGURE 2.11. **Main Reasons Why Interviewees Used Biogasoline E5 RON92**



Source: Study team.

FIGURE 2.12. **Main Reasons Why Interviewees Did Not Use Biogasoline E5 RON92**



Source: Study team.

2.2.3.3 Willingness to use biogasoline

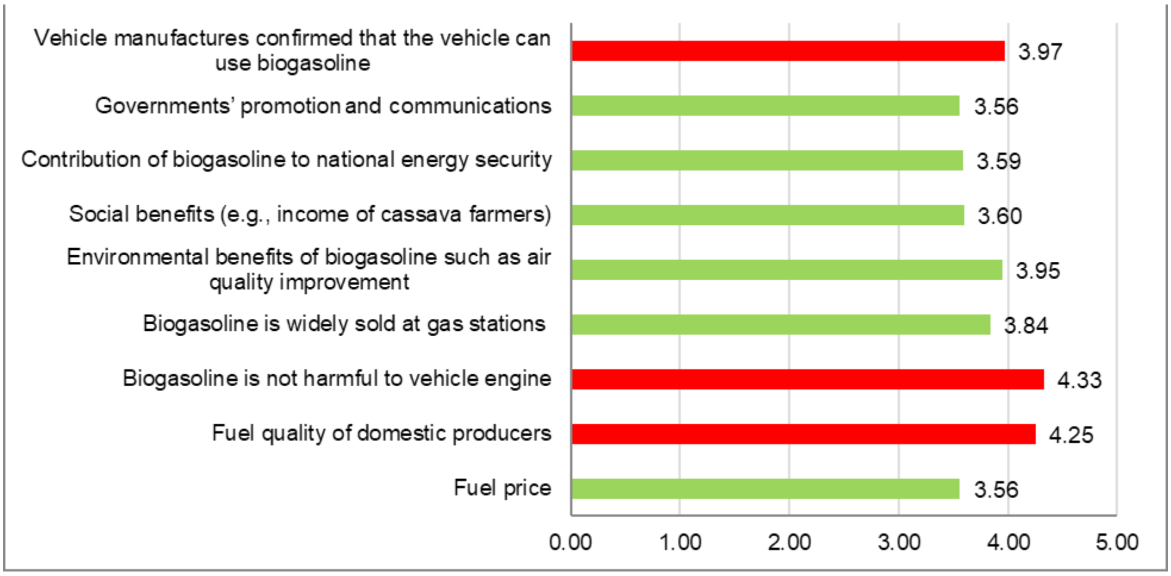
Regarding the willingness to use biogasoline, motorcycle and car drivers were asked their views on the importance of nine influential factors for their choices, including:

- Price of biogasoline
- Quality of biogasoline produced by domestic companies
- Safety of vehicle engine
- Availability of biogasoline at gas stations

- Environmental benefits of biogasoline
- Social benefits of biogasoline
- Contribution of biogasoline to national energy security
- Communications and supportive policies of government authorities
- Confirmation from vehicle manufacturers about the use of biogasoline.

The answer is scaled from 1 (very unimportant) to 5 (very important). Based upon interviewees' responses, an average score of each factor is estimated. The result indicates that the safety of vehicle engines has the highest score (4.33), followed by fuel quality (4.25) and confirmation from vehicle manufacturers (3.97). This result is logical and consistent since motorcycle and car drivers are mainly concerned with the quality of biogasoline and the safety of vehicle engines. There are two main policy implications. The first one is that biogasoline producers and government authorities must ensure the quality of biogasoline is in accordance with current regulations. The second is that vehicle manufacturers need to announce what types of biofuels their vehicles can use.

FIGURE 2.13. **Average Score of Factors Influencing People's Willingness to Use Biogasoline**



Source: Study team.

2.2.3.4 Supportive policies for biofuels

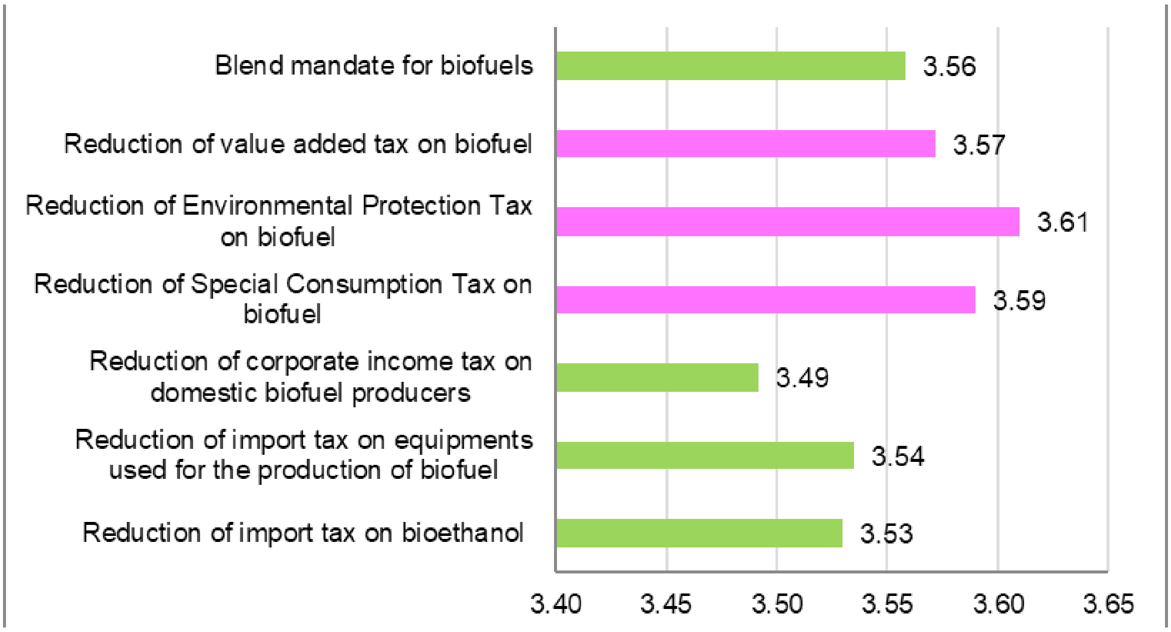
Finally, motorcycle and car drivers were asked for their views on supportive policies. They were given a list of seven policies, including:

- Import tax on bioethanol
- Import tax on equipment used for the production of biofuel

- Corporate income tax on domestic biofuel producers
- Special Consumption Tax (SCT) on biofuel
- Value added tax (VAT) on biofuel
- Environmental Protection Tax (EPT) on biofuel
- The blend mandate for biofuels.

The answer is scaled from 1 (very unimportant) to 5 (very important). Based on the responses of respondents, an average score of each policy is estimated. The policy for reduction of EPT tax for biofuel has the highest score (3.61), followed by SCT (3.59) and VAT (3.57). This result seems logical since motorcycle and car drivers shall benefit more from the reduction of those taxes.

FIGURE 2.14. **Average Score of Supportive Policies for Biofuels**



Source: Study team.

2.3 Scenario for Promoting Biofuels

2.3.1 Consultation with stakeholders

2.3.1.1 Consultation for biogasoline targets

Representatives of agencies only gave recommendations on targets to 2025. Specifically, representatives of the Department of Science and Technology in the MOIT recommended the share of biogasoline and biodiesel in total road gasoline and diesel could be 30 percent by 2025. This target is lower than the VN-NDC 2020's target but closer to the actual share in the period from 2015 to 2019. On the other hand, both interviewees from the Vietnam Biofuels Association (VBA) and the Vietnam Petroleum Association (VINPA) said that 40 percent of the total gasoline and diesel demand would be biofuel. This proposal is in line with the VN-NDC 2020 suggestion. It is noted that such recommendations have not been mentioned in any official documents.

TABLE 2.14. **Recommendations for the Share of Biogasoline**

Agency	Share of Biogasoline (%)				
	2025	2030	2040	2045	2050
DOST, MOIT	30%	-	-	-	-
VBA	40%	-	-	-	-
VINPA	40%	-	-	-	-

Source: Study team.

2.3.1.2 Consultation for blend mandate

Along with the blend mandate, interviewees were asked for their views on the percentage and date of ethanol blend rates for gasoline and diesel. All interviewees indicated that it may be feasible to use the ethanol blend rate of 10 percent in the period from 2021 to 2025. The recommended blend rate is consistent with that of Biofuel Roadmap No. 53.

TABLE 2.15. **Recommendations for the Ethanol Blend Rate**

Agency	Ethanol Blend Rate	When It Is Feasible to Implement
DOST, MOIT	10%	Gasoline E10: 2021–25
VBA	10%	Same as above
VINPA	10%	Same as above

Source: Study team.

2.3.1.3 Consultation on applicability of biofuels to other transport subsectors

Representatives of agencies were asked for an estimate of the potential for the use of biofuels in transport subsectors, except road transport. Interviewees answered questions on three key items:

- Feasibility of implementation (Yes/No)
- What period is feasible to introduce the policy?
- The target for the share of biofuel in each transport subsector.

Generally, interviewees indicated that railway transport may have the highest potential for the use of biofuels in the period from 2021 to 2025, followed by inland waterway transport in the period from 2026 to 2030. Aviation transport is considered to have the least potential for the use of biofuels.

TABLE 2.16. **Recommendations for the Use of Biofuels in Transport Subsectors**

Agency	Potential for the Use of Biofuels			
	Railway	Inland Waterway	Maritime	Aviation
DOST, MOIT	• Yes, in 2021–25 • 10% by 2025	• Yes, in 2026–30 • 10% by 2030	• Yes, in 2041–50 • 10% by 2050	• Yes, in 2041–50 • 10% by 2050
VBA	• Yes, in 2021–25 • 10% by 2025	• Yes, in 2026–30 • 30% by 2030	• Yes, in 2026–30 • 10% by 2030	No
VINPA	• Yes, in 2021–25 • 10% by 2025	• Yes, in 2026–30 • 30% by 2030	• Yes, in 2026–30 • 10% by 2030	No

Source: Study team.

Note: Recommendations do not include road transport.

2.3.2 Scenario recommendation

2.3.2.1 Biogasoline development scenario for the period from 2021 to 2030

Based on the analysis of policy orientations, barriers, and consultation results, the study team proposed the development scenario for biogasoline in 2021 to 2030 as follows:

- Type of blended fuels: According to the analysis of policies, the most feasible scenario is that only gasoline shall be used for the blending in the period from 2021 to 2030, and the diesel blending will not be implemented. Due to the lack of specific policies regarding the road map for diesel blending, B5 and B10 diesel have not been nationally commercialized. The experience in the national commercialization of E5 gasoline is that it took at least three to four years from the time the legal road map was promulgated. It takes time to prepare feedstock supply areas for ethanol plants and the construction of blending, storage, and transport systems. For biodiesel, feedstocks for the production of B100 diesel must be considered. On June 19, 2008, the Ministry of Agriculture and Rural Development (MARD) promulgated Decision No. 1842/QĐ-BNN-LN on "Approval of Scheme on Research, Development, and Usage of Products of Jatropha Curcas in Vietnam in the Period of 2007-2015 and a Vision to 2025." Jatropha has the potential for the production of B100. Up to now, however, the production of B100 is small-scale and just in the pilot phase. In conclusion, diesel blending has low feasibility in the period from 2021 to 2030 due to the lack of policies and deficiencies of production and blending infrastructures.

- The ethanol blending rate: According to the analysis of policies, the most feasible rates of ethanol are 5 percent (E5 gasoline) and/or 10 percent (E10 gasoline) in the period from 2021 to 2030.

- Market share of biogasoline: The share of biogasoline had a downward trend in the period from 2018 to 2020. According to the analysis of policies, there have been no policy breakthroughs such as a blend mandate for all types of gasoline or tax deduction policy. Therefore, the most feasible scenario is that the share of E5 gasoline will have a slightly decreasing trend in the period from 2020 to 2024, from 40 percent in 2019 to 30 percent in 2024. By 2025, it is proposed that the ethanol blending rate will be changed from 5 percent (E5 gasoline) to 10 percent (E10 gasoline). There are three main reasons for this proposal as follows:

- Shifting from E5 gasoline to E10 gasoline may lead to larger demand and market for ethanol. This may further promote the production activities of domestic ethanol plants.
- According to the policy analysis, shifting from E5 gasoline to E10 gasoline is the most feasible policy in terms of legal regulations because E10 gasoline has been regulated in the following legal documents:
    - The Biofuel Roadmap No. 53 in accordance with Decision No. 53/2012/QĐ-TTg
    - National technical regulation QCVN 03:2014/BCT on equipment, auxiliaries, and means for blending, storing, and transportation of ethanol and E10 gasoline at distribution terminals
    - National technical regulation QCVN 1:2015/BKHCN on gasoline, diesel oils, and biofuel.

  It is noted that the Ministry of Science and Technology (MOST) is formulating a Draft of National Technical Regulation QCVN 1:2020/BKHCN for replacement of QCVN 1:2015/BKHCN and Amendment 1:2017 QCVN 1:2015/BKHCN. According to the draft, there are only regulations regarding three types of biofuels—E5 gasoline, E10 gasoline, and B5 diesel.
- Key gasoline traders may not face difficulties in shifting from E5 gasoline to E10 gasoline since they can utilize existing blending, storage, and transport systems.

• Application of biofuels to other transport subsectors: According to the policy analysis, it is better to continue the blending for gasoline in road transport subsectors, and biofuels have not been applied to other transport subsectors. Up to now, there have been no specific policies for the application of biofuels in the period from 2021 to 2030. Additionally, the experience in the national commercialization of E5 gasoline is that it took at least three to four years from the time the legal road map was promulgated. Hence, it has a low possibility for the application of biofuels to other transport subsectors.

In conclusion, the proposed scenario is as follows: The share of E5 gasoline will have a slightly decreasing trend in the period from 2020 to 2024, and it will reduce to 30 percent by 2024. By a policy intervention, E10 gasoline will be used in road transport subsectors by 2025. It is assumed that the amount of ethanol used for E10 gasoline in 2025 will be equal to such amount used for E5 gasoline in 2024. The share of E5 gasoline is projected to be 30 percent in 2024, so it may be inferred that the share of E10 gasoline will be 15 percent in 2025. Then, the share of E10 gasoline will gradually rise to 30 percent by 2030.

2.3.2.2 Proposed supporting policies

• Feedstock supply for production of ethanol:

- The period from 2021 to 2025: The first thing is to maintain existing orientation policies for volume and plantation area of cassava (i.e., 10 million to 11 million tons and 500 hectares) as well as incentives for cassava farming and processing in accordance with Decree No. 55/2015/NĐ-CP on “Credit Policy for Agricultural and Rural Development” and Decision

No. 68/2013/QĐ-TTg on "Supportive Policy for Mitigation of Losses in Agricultural Sector." Additionally, it is necessary to formulate a plan of dedicated feedstock area for domestic ethanol plants.

- The period from 2026 to 2030: Alternative feedstock (e.g., industrial crops) must be considered when demand for ethanol is increased. In existing policies, only cassava is selected as feedstock for the production of ethanol. It is necessary to formulate and promulgate policies regarding alternative feedstock for the production of ethanol in Vietnam.

• Supply of ethanol: The mechanism of linkage from farming and processing to consumption of cassava products must be formulated by utilizing incentives in accordance with Decree No. 98/2018/NĐ-CP on "Incentive Policies for Development of Linkage in Production and Consumption of Agricultural Productions." This may lead to a stable feedstock supply for domestic ethanol plants. Additionally, there will be a growth of demand for ethanol due to the shifting from E5 gasoline to E10 gasoline. Existing ethanol plants need to scale up capacity (for plants with stable operation) or restart their operations (for plants with discontinuous operations due to financial loss). Hence, it is necessary to provide loans with preferential interest rates for existing ethanol plants for capacity expansion or reoperation.

• Biogasoline supply: Key gasoline traders need to invest and expand the capacity of the blending system due to the shift from E5 gasoline to E10 gasoline. Incentives include an exemption from import tax on machines and equipment used for blending biogasoline, which is crucial to encourage key traders to expand the blending system. The MONRE should promulgate a list of imported machinery, equipment, vehicles, tools, and supplies used for environmental protection by Decree No. 134/2016/NĐ-CP "Guidelines for the Law on Export and Import Tax."

• Biogasoline consumption: Providing purchasing incentives that can increase the price gap between biodiesel and existing diesel oils, such as reducing VAT, EPT, and SCT.

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3. Assessment of the Use of CNG Buses According to NDC Commitments and Recommendations for CNG Bus Development Scenarios

3.1 Introduction

According to the updated Nationally Determined Contribution (NDC) 2020 and research in the 2019 World Bank report (Oh et al. 2019), the measure to promote compressed natural gas (CNG) buses can be implemented using domestic resources. Accordingly, the target of the transport sector is to develop 623 CNG buses by 2030. The implementation of CNG buses is considered to reduce 3,000 tons of CO_2 by 2030, cumulatively accounting for 64,000 tons of CO_2 emissions reduction against business as usual (BAU) between 2015 and 2030.

With the base year selected as 2014, policy interventions for greenhouse gas (GHG) mitigation and actual implementation efforts have been considered starting from 2015 and continuing until 2030. Up to now, important questions to be answered in the CNG bus research include:

1) During the period from 2015 to 2020, how successful was the effort by the transport sector in developing the size of the CNG bus fleet? How much of the NDC commitment target has been met?

2) Can it be recommended to increase the target of the CNG bus fleet size more than the NDC commitment on the basis of policy analysis and market analysis?

To answer the above two questions, the content of this section will first evaluate the GHG mitigation results (efforts and achievements) of the transport sector over the period from 2015 to 2020 and compare this achievement with the NDC 2020 target. The following section will analyze trends and prospects for the development of CNG buses based on a review of updated policies, CNG bus development targets in several major cities, and consultations with bus enterprises, and assess the availability. Based on the assessment of targets and the enterprise's readiness, the number of CNG buses will be projected. Finally, a road map to ensure the size of the CNG bus fleet will be recommended.

3.2 Transport Sector's Efforts and Achievements in Deploying CNG Buses

3.2.1 Existing policies to promote CNG buses in Vietnam

Between 2010 and 2020, the Ministry of Transport (MOT) developed and issued many important policies related to the development of public transport vehicles using clean fuel, contributing to ensuring the goal of reducing GHG emissions; at the same time it concretized the commitments of the transport sector in the action plan to respond to climate change and green growth.

3.2.1.1 Contribution of the transport sector to the promulgation of national policies

The transport sector has integrated the development of public transport in national policies, such as the Green Growth Strategy, Climate Change Strategy, and Environmental Protection Strategy.

TABLE 3.1. **National Policies Related to the Development of Public Transport**

Policies	Documents	Main Content	Quantitative Objective
Green Growth Strategy	1393/QD-TTg	• Encourage shift to CNG and LPG for passenger transport	-
Climate Change Strategy	2139/QD-TTg	• Increase use of CNG and LPG in 20% and 80% of public vehicles by 2020 and 2050, respectively	2020: CNG buses account for 20% of total vehicle fleet 2050: CNG buses account for 80% of total vehicle fleet
Environmental Protection Strategy	1216/QD-TTg	• Promulgation of incentive policies for transport vehicles using renewable energy, vehicles with low fuel consumption or low emission	-

Source: Study team.

The MOT issued Decision 1456/QD-BGTVT in 2016 on the "Action Plan to Respond to Climate Change and Green Growth of the Transport Sector for the Period From 2016 to 2020." In this plan, the MOT has proposed five goals and six groups of solutions, in which "Promoting the use of clean energy in transportation, 5-20% of buses will use CNG, LPG or solar energy by 2020" is among the five important goals.

Besides Decision 1456/QD-BGTVT, regulations related to changing fuel structure toward sustainability are mainly focused on public transport by bus and taxi. In general, the policy on public transport development is integrated into the Transport Service Development Strategy (Decision 318/QD-TTg), the Transport Development Strategy (Decision 355/QD-TTg), and the Road Network Planning (Decision 356/QD-TTg). Policies related to the development of bus fleet using clean fuel are emphasized in the following legal documents:

- Mechanism and policy for the development of public transport by bus (Decision 13/QD-TTg)

- Project on improving the quality of public transport by bus until 2020 (Decision 3446/QD-BGTVT)

- Project on the development of public transport by bus over the period from 2012-2020 (Decision 280/QD-TTg)

- The scheme for rational development of transportation modes in major cities of Vietnam.

These documents all partly mention the importance of incentives for clean-energy vehicles, including CNG buses.

The most important preferential policy is Decision 13/2015/QD-TTg dated May 5, 2015, on "Mechanisms and Policies to Encourage the Development of Public Passenger Transport by Bus." According to Clause 5 of Article 3, a clean-energy bus means liquefied gas, natural gas, or electric buses. In addition, the refueling station/charging station is part of the infrastructure system serving buses (as in Clause 2, Article 3). There are four types of incentives:

- Incentives for the investment of infrastructure system development: The investor is prioritized to access preferential loans, including official development assistance (ODA) loans and preferential credit loans. Additionally, the investor may receive the support of provincial or central-level people's committees for loan interest rates.

- Incentives for the investment of vehicles: First, bus operators can be exempted from import duty on domestically unavailable parts and components for the manufacture and assembly of vehicles. Second, the investment in clean-energy buses is exempted from registration fee. And third, bus operators may receive the support of provincial or central-level people's committees for loan interest rates.

- Incentives for the operation of public bus passenger transport: Bus operators may receive a subsidy or support for the operation cost.

- Incentives for bus users: First, children below the age of six and the disabled are exempt from bus fare. Second, persons with meritorious services to the revolution, the elderly, and students may receive a discount on bus fare.

TABLE 3.2. **Sectoral Policies Related to the Development of Public Transport in Vietnam**

Policies	Documents	Main Content	Quantitative Objective
Project on development of public transport by bus in the period from 2012 to 2020	280/QD-TTg	• Priority is given to the application of modern, safe, and environmentally friendly technologies for vehicle fleet	
Mechanisms and policies to encourage the development of public transport by bus	13/QD-TTg	• Develop criteria to determine transport operators using a clean vehicle fleet as the basis for registration fee exemption • Step by step, structure the vehicle fleet in the direction of reducing the average age, prioritizing vehicles that use clean fuel	
Action plan to respond to climate change and green growth	1456/QD-BGTVT	• Promote the use of biofuels, clean fuels (CNG, LPG, etc.) for motor vehicles	5–20% of total bus fleet
Project to improve the quality of public transport by bus until 2020	3446/QĐ-BGTVT	• Prioritize vehicles that use clean fuel, ensuring the ratio of vehicles to assist people with disabilities	
The scheme of rational development of modes of transport in major cities of Vietnam		• Innovate means and structure of public passenger transport by bus, prioritizing environmentally friendly buses (buses using LPG, CNG, etc.)	

Source: Study team.

3.2.1.2 Promulgation of sectoral policies at the city level

At the local level, preferential policies on vehicles using clean fuel are divided into three groups: policies to support infrastructure investment, policies to support investment and procurement of vehicles, and policies to support bus operation.

The review process was carried out in five major cities (Hanoi, Hai Phong, Da Nang, Ho Chi Minh City, and Can Tho) because of two reasons. First, the development of public transport mainly occurs in these cities. And second, bus enterprises in these cities can easily access preferential capital sources during the business operation.

TABLE 3.3. **Policies to Support Public Transport Activities**

Financial Incentives	Hanoi	Hai Phong	Da Nang	Ho Chi Minh City	Can Tho
1. Investment of Bus Infrastructure					
1.1. Exemption from the rent for land	Yes (100% in first 10-year period)	Yes	Yes	Yes	Yes
1.2. Access to preferential loans: ODA or concessional loans	Yes (BRT Line 1)	Yes (just general orientation)	Proposed (BRT project)	Proposed (BRT project)	No
1.3. Support for loan interest rate	Yes (50% in first 5-year period)	No	No	No	No
2. Investment of Bus Vehicles					
2.1. Purchase of bus vehicles by local budget	Yes (only for state-owned operators)	No	No	Yes (only for state-owned operators)	No
2.2. Purchase of bus vehicles by ODA loans	Yes (just orientation)	No	No	No	No
2.3. Exemption from import duty/ tax for domestically unavailable parts and components	Yes	Yes	Yes	Yes	Yes
2.4. Support for loan interest rate	Yes (clean-energy bus: 50% in first 5-year period)	Yes (50%, up to 5 years)	No	Yes (clean-energy bus: operators pay for 3%, up to 7 years)	Yes (in policy, but not yet implemented)
2.5. Exemption from registration fee (clean-energy vehicles)	Yes (for CNG bus)	Yes (in policy, not yet implemented)	Yes (in policy, not yet implemented)	Yes (for CNG bus)	Yes (in policy, but not yet implemented)
3. Operation of Public Bus Transport					
Subsidy for the operation of public bus passenger transport	Yes (as of 2019,100 subsidized routes)	Yes (4 subsidized routes)	Yes (12 subsidized routes)	Yes (106 subsidized routes)	Yes (in policy, but not yet implemented)

Sources: Hanoi: Resolution No. 07/2019/NQ-HDND (2019); Plan No. 201/KH-UBND (2020); Hai Phong: Decision No. 231/2017/QD-UBND (2017); Decision No. 22/2018/QD-UBND (2018); Da Nang: Decision No. 5773/QD-UBND (2019); Ho Chi Minh: Decision No. 2398/QD-UBND (2013); Decision No. 3998/2020/QĐ-UBND; Can Tho: Decision No. 1245/QD-UBND (2018); Nha Trang: Decision No. 30/2018/QD-UBND (2018); and Ha Long Resolution No. 147/2018/NQ-HDND (2018); Decision No. 2307/QD-UBND (2019).

The policy review shows that there is a gap between promulgation and implementation. Some cities promulgated policies but have not been able to apply them due to limited financial resources. For example, the subsidy policy has been promulgated in five cities, but only four implemented the supports to bus operators. The government of Can Tho still does not provide any financial incentives for bus operators in this period, so the bus network in the city is underdeveloped. Furthermore, only three out of five cities (Hanoi, Hai Phong, and Ho Chi Minh City) have decided to provide financial incentives, such as low bank loan interest rates, to bus operators so that they can buy buses.

3.2.2 Contributions to GHG emissions mitigation

After many efforts at promoting CNG buses in major cities in Vietnam, the number of CNG buses has sharply increased. As of June 2021, there were 708 CNG buses, an increase of 7.4 times compared to 2014. The CNG buses were recorded at 5.3 percent of the total vehicle fleet. At the end of 2020, there were 672 CNG buses, which met the NDC 2020 target and the MOT's action plan. However, CNG buses only operate in Ho Chi Minh City (495 units), Hanoi (129 units), and Binh Duong (84 units). This shows the difficulties in expanding CNG buses across the country due to the unavailability of refueling stations, gas prices, and maintenance-related issues. The list of bus operators who are operating CNG buses is presented in Appendix B.

TABLE 3.4. **Statistics of CNG Buses in Vietnam**

	2014	2015	2016	2017	2018	2019	2020
Total number of busesa	11,053	11,766	11,948	12,130	12,311	13,067	13.253
CNG buses	96	108	238	425	528	658	672
CNG bus/total fleet	0.9%	0.9%	2.0%	3.5%	4.3%	5.0%	5.1%
Compared to the action plan to respond to climate change and green growth	By 2020, the rate of CNG buses will be between 5% and 20%						Meet the target
Compared to updated NDC	In the period from 2020 to 2030, the number of CNG buses is 623						Meet the target

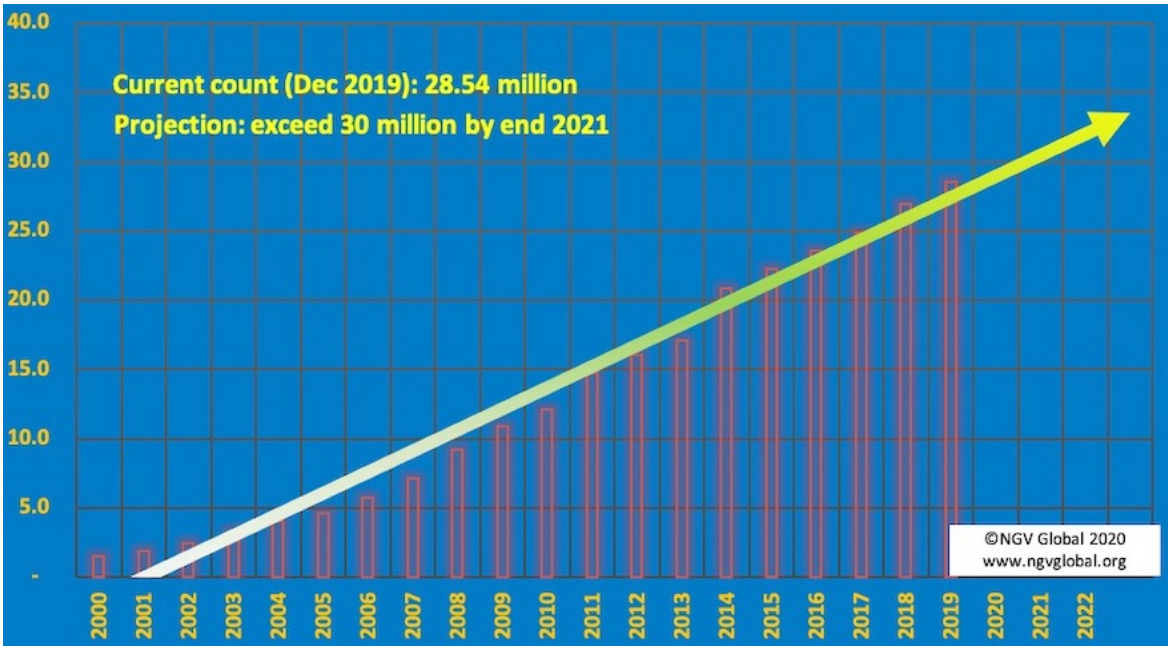
Source: The data for the period from 2014 to 2020 are referenced from the Directorate for Road of Vietnam and adjusted according to the statistics of the Vietnam Register in June 2021.

3.3 Analysis of the Trend of CNG Buses in the Period from 2021 to 2030

3.3.1 International experience in CNG bus promotion

The global natural gas vehicle (NGV) market reached 28.54 million vehicles in 2019 and is expected to grow at an average annual rate of 3.3 percent in the period from 2021 to 2028. The global NGV vehicle structure shows the prevalence of passenger cars and light commercial vehicles (92 percent) powered by CNG, while the number of LNG-fuelled heavy-duty vehicles, such as trucks, buses, water, and rail transport, remained low. Among the main reasons is the nascent LNG technology, which leads to higher LNG prices. Currently, the transition to LNG is only economically feasible in the case of long-haul trucks.

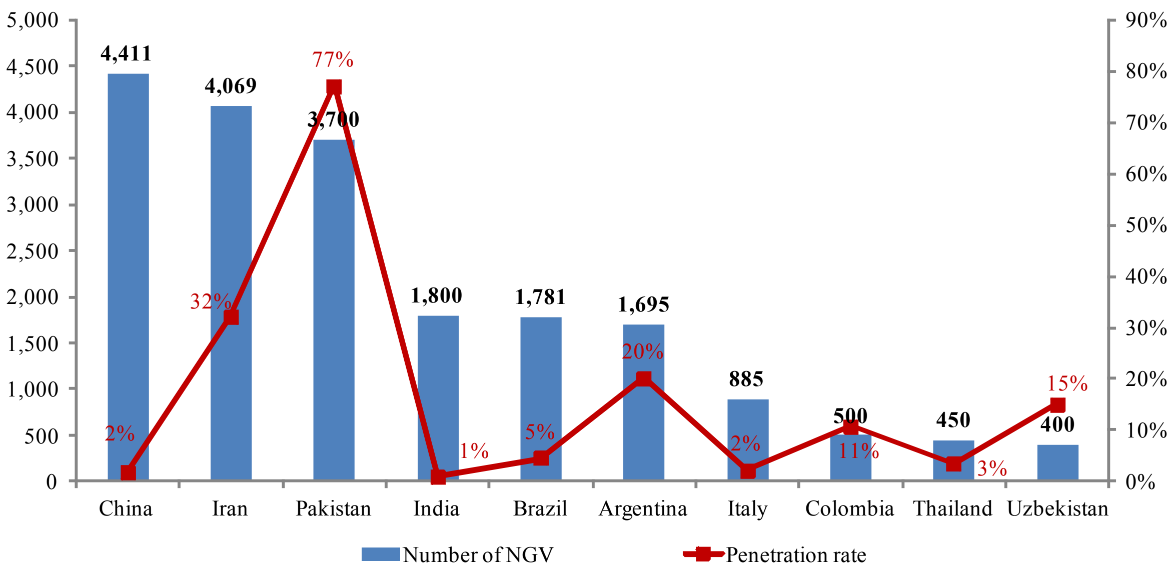
FIGURE 3.1. **Development of NGVs Around the World**



Source: See ANGVA website at http://www.angva.org/?page_id=256.

Six of the top 10 countries with the largest NGV fleets are situated in Asia, including the three leaders, namely China, Iran, and Pakistan. Pakistan and Iran are characterized by the highest penetration of gas-fueled vehicles in the world—77 percent and 32 percent, respectively.

FIGURE 3.2. **Top 10 Countries with the Largest NGV Fleet**



Source: See ANGVA website at http://www.angva.org/?page_id=256.

Note: Data in thousands.

Instruments that proved to be efficient in leading national NGV markets include customer and demand support measures and infrastructure and supply development support measures:

- Customer and demand support measures:
    - Incentives that support favorable price differential between gasoline/diesel and natural gas for fuel purposes as this is a primary factor of choice for customers and infrastructure investors
    - Incentives designed to bring down initial costs of conversion kit installation/new NGV purchase by customers: subsidies, lower taxes and import duties, low-interest loans, accelerated depreciation of investments, etc.
    - Technological, safety, economic, and information support
    - Development of a regulatory framework to ensure smooth market operation
    - Proactive measures to organize cooperation between key NGV market stakeholders
    - Ecological policy setting emission standards and providing nonfinancial incentives to environment-friendly modes of transportation (such as all-day weekly parking in city centers, etc.).
- Infrastructure and supply development support measures:
    - Realization of pilot projects and stimulation of private investment in the NGV refueling network, conversion, and service centers (land allocation on a priority basis, simplification of the licensing process etc.)
    - Simplification of private investment procedures, including allocation of land for NGV infrastructure objects, special-purpose loans, etc.
    - Support of research, development, and manufacture of NGVs, conversion kits, and other equipment. For instance, Argentina has developed highly effective conversion technologies and exports them to other countries
    - Pilot projects of public transport and municipal vehicle conversion to CNG fueling tendering terms preferential to suppliers of environment-friendly transport
    - Establishing well-developed technological and safety standards, verification, and certification procedures.

TABLE 3.5. **Combined Analysis of State Support Measures for the NGV Industry in the Leading National NGV Markets**

Criteria/Country	China	Iran	Italy	Thailand	Republic of Korea	Pakistan	Argentina	Brazil	Bangladesh	Colombia	India	Uzbekistan	United States of America	TOTAL
Demand and customers support measures														
Tax benefits	+	+	+	+	+	+	-	+	+	-	-	-	-	8
Restrictions for conventional vehicle movement and parking	+	-	+	-	+	+	-	-	+	-	+	-	-	**6**
Soft-terms loans/subsidies for conversion to gas or purchase of a new natural gas vehicle	+	-	+	+	-	+	-	+	+	+	-	-	+	**8**
Commercial and social preferences for NGV operators	+	+	+	-	-	-	-	-	-	-	-	-	-	3
State regulation of prices for CNG/LNG	+	-	-	+	+	-	+	-	-	+	+	+	-	**7**
Penalties for usage of gasoline/diesel-fueled vehicles	-	-	+	-	-	-	-	-	-	-	+	-	-	**2**
NGV infrastructure development support measures														
Tax benefits/subsidies/grants for CNG/LNG infrastructure	+	+	+	-	+	+	-	+	-	-	-	-	+	**7**
State financing and participation in CNG/LNG infrastructure investment projects	-	+	-	+	-	-	+	+	-	+	-	+	-	**6**
Soft-term loans/accelerated land allocation, connection of communications, certification, registration, etc.	-	+	-	+	+	-	+	-	+	+	-	-	-	**6**
State financing and participation in NGV and conversion kits production and service infrastructure investment projects	+	-	-	-	-	+	+	-	-	-	-	+	-	4
Development of NGV regulations and standards	+	+	-	+	+	+	+	-	-	-	-	-	-	**6**
Tax benefits/subsidies/grants for NGV producers, conversion, and service centers	-	+	-	+	-	-	-	-	+	-	-	-	-	**3**
Other measures	-	-	+	-	+	-	-	+	-	-	-	-	-	**3**
TOTAL	**8**	**7**	**7**	**7**	**7**	**6**	**5**	**5**	**5**	**4**	**3**	**3**	**2**	

\+ – availability/planned introduction of support measures; - – the absence of support measures/unknown

Sources: NGVA and open sources.

3.3.2 Development of natural gas supply

According to statistics, about 84 percent of the total amount of natural gas in Vietnam, or 8.9 billion cubic meters (bcm), was produced in 2019. Crude oil and natural gas are being exploited mainly in the south offshore, but reserves are expected to be exhausted by 2020 to 2030 (MOIT 2019).

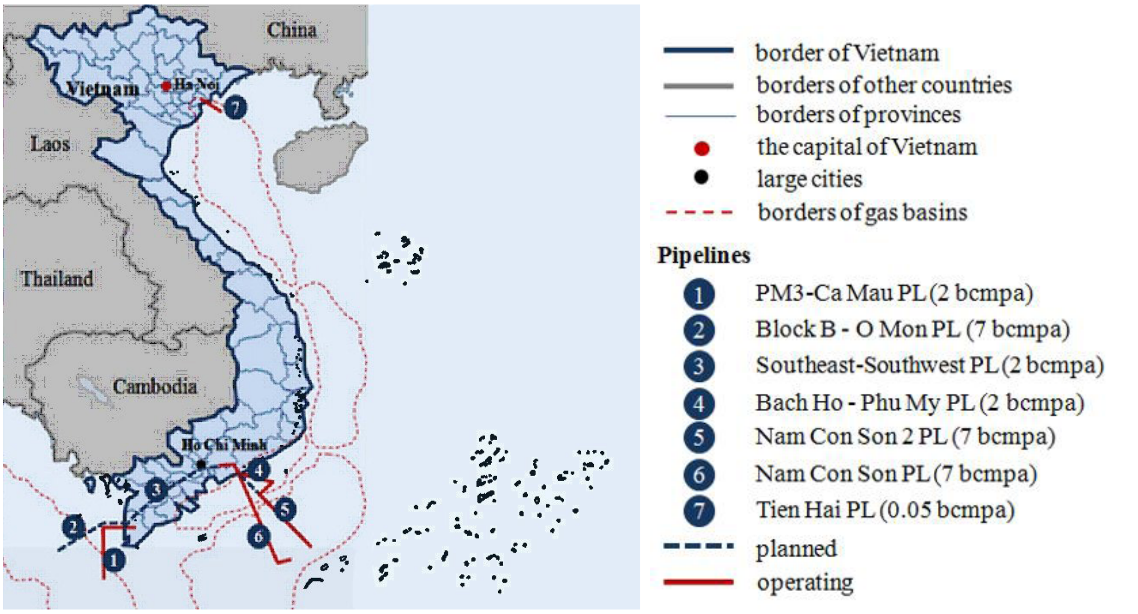
Vietnam's gas pipeline network consists of high-pressure lines from gas fields, gas processing plants, and a distribution network.

There are three transportation pipelines from the Southern region gas fields. Nam Con Son 1 pipeline accounts for the majority of Vietnam's gas supply and has a capacity of 7.3 bcm. Two other pipelines, one from the PM3 Commercial Arrangement Area to Ca Mau and the other from Bach Ho to Phu My, have comparable capacities of between 1.5 bcm and 2 bcm.

A pipeline in the Northeastern region was constructed in 1981 and is characterized by a high degree of wear.

In December 2015, Phase 1 of the Nam Con Son 2 pipeline construction project was completed. It has been built to take gas from the Dai Hung gas field and is connected to Bach Ho-Dinh Co-Phu My to deliver gas to customers. After the completion of Phase 2, Nam Con Son 2 pipeline will deliver gas directly to processing plants and end users.

FIGURE 3.3. **Gas Transportation and Distribution Network in Vietnam**



Source: PetroVietnam.

There is only one gas processing facility in Vietnam currently, namely the Dinh Co Gas Processing Plant. It processes gas from Cuu Long and Nam Con Son basins.

The gas distribution pipeline network is tiny and exists in about 10 provinces out of 63.

TABLE 3.6. **Gas Pipeline Network in Vietnam, 2019**

Region/ Basin	Basin	Gas Transportation Pipeline (construction year)	Capacity, bcm/ year	End Point	Distribution Pipelines from the Transportation Pipeline	Final Consumers
Northeast	Red River	Thai Binh/Ham Rong fields- Tien Hai (1981)	0.03–0.05 (no data on diameter)	Gas Distribution Center in Tien Hai	Not specified	Tien Hai Industrial Zones in Thai Binh province and neighboring provinces in the Northern Region
Southeast	Cuu Long	Bach Ho- Dinh Co-Phu My (1995)	1.5 (16-inch diameter)	Dinh Co Gas Processing Plant (processing associated wet gas)	Dinh Co-Ba Ria-Phu My	Power plants, fertilizer plant in Vung Tau and other industrial customers in Ba Ria-Vung Tau province
Southeast	Nam Con Son	Nam Con Son 1 (2002)	7.3 (26-inch diameter)		Phu My-Nhon Trach-Hiep Phuoc	- Power plants in Nhon Trach area and industrial zones alongside the pipeline - Plans to deliver gas to Ho Chi Minh City and Southeast-Southwest pipeline in the future
Southeast	Nam Con Son	Nam Con Son 2, phase 1 (Dec. 2015)	7.3 (26-inch diameter)	Bach Ho-Dinh Co-Phu My		
					Phu My-My Xuan-Go Dau	Low-pressure gas consumers in Phu My-My Xuan-Go Dau industrial zones
Southwest	Malay-Tho Chu	PM3-Ca Mau (2007)	2.2 (18-inch diameter)	Directly to final consumers (Ca Mau Gas Processing Plant under construction)		Power plant and fertilizer plant in Ca Mau province, O Mon power plants in Can Tho city

Source: PVN.

Vietnamese state authorities are planning to overcome the limitations of local gas reserves and prevent the projected gas shortage by importing LNG. Because the price of imported LNG is considerably higher than that of domestic gas, target customers will be those who can afford it, including state-owned power plants.

The PV GAS company has signed an agreement on the front-end engineering and design (FEED) and a memorandum of mutual understanding with Tokyo Gas Co. The two companies have created the LNG Vietnam Joint Stock Company (LNG Vietnam JSC). Vietnam's main LNG suppliers are Australia, Russia, and Qatar.

According to the state's plans, one LNG import terminal each will be constructed in Thi Vai (BR-VT) and Son My (Binh Thuan).

TABLE 3.7. **LNG Import Terminal Construction Projects in Vietnam**

LNG Import Terminal	Planned Launch Date	Annual Capacity	Proposed End Users
Thi Vai (BR-VT)	2018	1.0 Mt (1.4 bcm)	Industrial facilities (connection through Thi Vai-Phu My pipeline)
Son My (Binh Thuan)	Phase 1: 2022 Phase 2: 2025	Phase 1: 3.6 Mt (5.0 bcm) Phase 2: 2.4 Mt (3.3 bcm)	Construction of new 4,000 MW power station and development of Southeast market

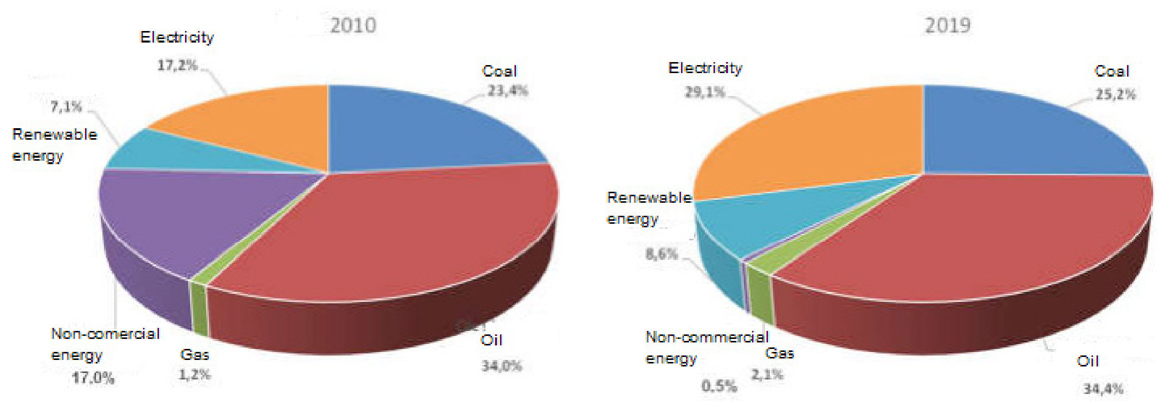
Source: PVE 2016.

3.3.3 Increase in natural gas demand

3.3.3.1 Natural gas demand

The total energy consumption in Vietnam in the last nine years has risen 1.3 times to 61.8 megatonne of oil equivalent (Mtoe), and the share of natural gas in 2019 was 2.1 percent compared to 1.2 percent in 2010. Crude oil and natural gas are being extracted mainly offshore in the south, but the reserves are expected to be depleted by 2020 to 2030 (MOIT 2019).

FIGURE 3.4. **Final Energy Consumption in Vietnam Between 2010 and 2019**



Source: MOIT 2018.

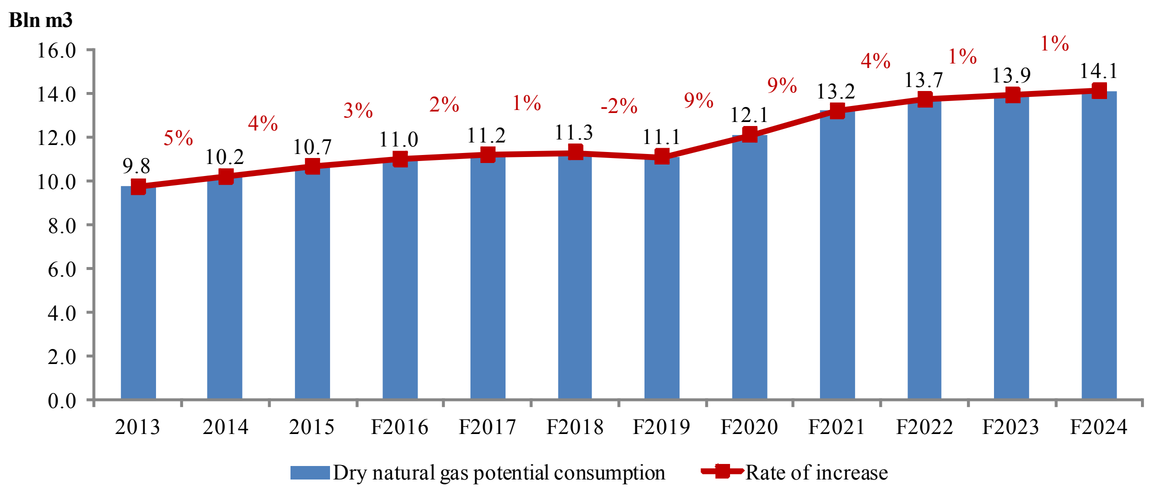
The total consumption of natural gas in 2019 was 1,455 million m^3 (mcm). Between 2013 and 2015, gas market growth slowed to 4 percent per year due to a lack of production capacities.

The demand for natural gas in Vietnam grows in line with the total energy market growth. A list of natural gas segment-specific growth drivers, includes:

- Lack of new oil field discoveries. Oil production grew by 2.0 percent between 2016 and 2018 driven by additional production at Te Giac Trang field and utilization of enhanced oil recovery techniques at mature fields (PetroTimes 2021). But since 2019, domestic oil production gradually decreased due to the aging of oil fields.

- Increase of gas-fueled energy production. Gas-fueled power generation constituted 21 percent of the total national energy output in 2014 (ADB 2015). PVE forecasts that in the short term, this ratio will increase to 31 percent, even after considering the forecasted growth of coal usage (PVE 2016). Wood Mackenzie holds a more conservative opinion (Wood Mackenzie 2015). It expects the share of gas to remain at 20 percent to 23 percent between 2017 and 2035 and the share of coal to exceed 50 percent by 2035 compared to 28.6 percent in 2014. Both forecasts agree that the demand for gas for power generation will grow at least in line with general power generation growth rates.
- The government plans to promote the use of gas in the transport sector in order to reduce air pollution in major cities.

FIGURE 3.5. **Vietnam's Natural Gas Demand Forecast**



Source: PVE 2016.

According to PVE, the demand for gas in Vietnam between 2016 and 2024 will increase from 11.0 bcm to 14.1 bcm, or at a rate of 3.2 percent per annum.

3.3.3.2 Gas demand in transportation

In 2019, the total consumption of CNG as a transport fuel in Vietnam was estimated at 108 mcm. LNG is not currently used in Vietnam as vehicle fuel.

CNG for transportation in the Southern region is supplied by eight filling stations owned by two companies: PV GAS South and CNG Vietnam. These companies sell the bulk of the CNG produced to industrial customers (steel, construction materials, knitwear, beverage manufacturers, etc.). NGV refueling business constitutes only a small part of PV GAS South and CNG Vietnam's total output.

All CNG filling stations are located in the cities of Ho Chi Minh City and Ba Ria-Vung Tau, and Binh Duong province. The total annual capacity of the stations is equal to 11,500 standard cubic meter per hour (Sm^3/hour), or around 84 mcm per annum, which characterizes the existing NGV refueling infrastructure in Vietnam as operating largely under capacity with an average utilization rate of 5 percent.[1] The average age of the filling stations does not exceed five years, and the depreciation ratio is under 20 percent.

TABLE 3.8. **CNG Filling Stations in Vietnam, 2019**

№	Company	Filling Station	Capacity, Sm3/hour	City/ Province	Address
1	PV GAS South JSC	Pho Quang	2,000	Ho Chi Minh City	No. 2 Pho Quang Street, Tan Binh District
2		An Suong	2,000	Ho Chi Minh City	An Suong bus station, Hoc Mon District
3		Tan Kien	2,000	Ho Chi Minh City	Block 4B/12A, Hamlet 2, Tan Kien Commune, Binh Chanh District
4		The National University station	2,000	Ho Chi Minh City	The National University, Ho Chi Minh City
5		Nguyen An Ninh	500	Ba Ria-Vung Tau	No. 449, Nguyen An Ninh Street, Thang Nhat Ward, Vung Tau City
6		PCT	500	Ba Ria-Vung Tau	No. 654, Nguyen An Ninh Street, Ward 8, Vung Tau City
7		Mobile filling stations	500	Ba Ria-Vung Tau	No. 654, Nguyen An Ninh Street, Ward 8, Vung Tau City
8	CNG Vietnam JSC (PV GAS subsidiary)	Combined with a station for industrial customers	2,000	Binh Duong	My Phuoc industrial zone
TOTAL		-	**11,500**	-	-

Source: PVE 2016.

Besides PV GAS South and CNG Vietnam JSC, there is another potential CNG supplier for the transport industry in Vietnam—PetroVietnam Low Pressure Gas Distribution JSC (PV GAS D). This company operates natural gas compression facilities in the Northern region for industrial use and has the potential to enter the Southern region's NGV refueling market in the future. PV GAS D develops, invests in, and operates PVN's low-pressure gas distribution system in industrial zones across the country.

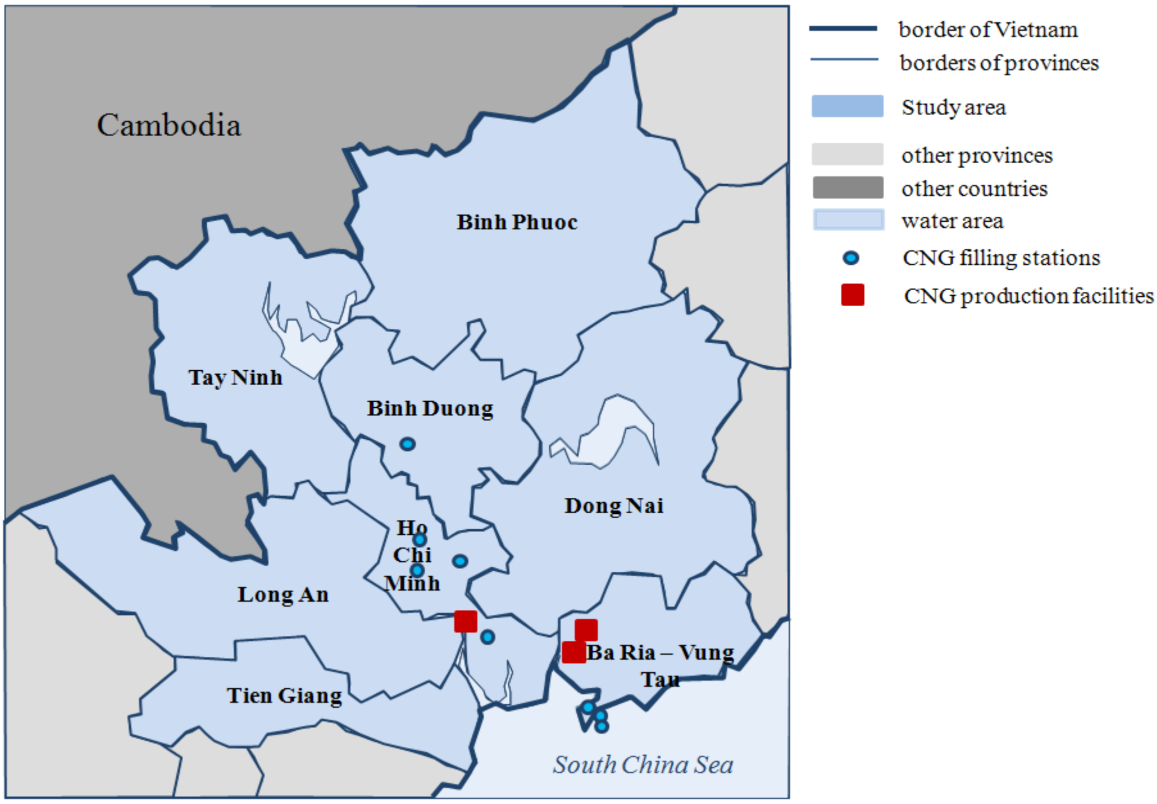
TABLE 3.9. **CNG Production Facilities in Vietnam, 2019**

Company	Address	Capacity, mcm/year	Province
PV GAS South	My Xuan A industrial zone	70	Ba Ria-Vung Tau
	Hiep Phuoc industrial zone	8	Ho Chi Minh City
CNG Vietnam	Phu My I industrial zone, Tan Thanh District	100	Ba Ria-Vung Tau
PV GAS D	Tien Hai industrial zone, Tien Hai District	No data	Thai Binh (Northern region)

Source: PVE 2016.

In 2013, PVN and Gazprom created a joint venture called PVGAZPROM Natural Gas for Vehicles to develop NGV refueling infrastructure in the Southern region of Vietnam.[2] On October 15, 2015, the Investment Planning Department of Ho Chi Minh City issued the registration certificate. The objectives of the company creation include the construction of cryogenic and multi-fuel filling stations.

FIGURE 3.6. **CNG Filling Stations and Production Facilities in Southern Vietnam**



Source: PVE 2016.

At present, CNG refueling infrastructure in the Southern region of Vietnam is largely underdeveloped. All the facilities are established by PV GAS and its daughter companies. Therefore, the refueling market can be characterized as monopolized.

3.4 Orientation for Development of CNG Buses

3.4.1 Agencies' targets and road map

Representatives of five Departments of Transport (DOTs)—in Hanoi, Hai Phong, Da Nang, Ho Chi Minh City, and Binh Duong—were consulted about some aspects of CNG bus policies, including: targets, road map, and supportive policies. The agencies' recommendations are summarized in the following sections. These recommendations have not been mentioned in any official documents.

TABLE 3.10. **Recommendations for the Share of Low-Carbon Vehicles**

Agency	The Share of CNG Buses (%)				
	2025	2030	2040	2045	2050
Hanoi DOT	5%–20%	5%–20%	-	-	-
Hai Phong DOT	5%	15%	35%	-	-
Da Nang DOT	5%–15%	5%–15%	-	-	-
Ho Chi Minh City DOT	N/A	N/A	-	-	-
Binh Duong DOT	10%–20%	10%–20%	10%–20%	-	-
Can Tho DOT	13.1%	8%	0%	-	-

Source: Study team.

According to the DOTs, the market share of public transport in big cities is meager. This is a barrier to developing low-emission vehicles because these vehicles have relatively high investment costs compared to conventional bus fleets.

TABLE 3.11. **Potential to Expand the CNG Bus Market in Vietnam**

Agency	Demand for Using CNG Bus	Mode Share of Public Transport
Hanoi DOT	Yes, high	Low, less than 10%
Hai Phong DOT	Yes, low	Low, less than 1%
Da Nang DOT	Yes, high	Low, less than 1%
Ho Chi Minh DOT	N/A	N/A
Binh Duong DOT	Yes, low	Low, less than 2%
Can Tho DOT	Low	Low, less than 1%

Source: DOT survey.

Initiatives in support of CNG-fueled public transport exist in four out of the five cities and one province. Ho Chi Minh City is considered as the leader on CNG buses in Vietnam. The city combines different policies to promote the market, including implementation of pilot projects, cooperation with NGV manufacturers, tax preferences, subsidies, and development planning of environment-friendly vehicles.

TABLE 3.12. **Policy Incentives for Transport Operators in Vietnam**

Agency	Encourage New Investor	Loan Support	Fee Support	Infrastructure Support	Mention CNG Bus in Public Transport Planning
Hanoi DOT	√	√	√	√	√
Hai Phong DOT	O	O	O	O	√
Da Nang DOT	√	√	√	√	√
Ho Chi Minh DOT	√	√	√	√	√
Binh Duong DOT	√	√	√	√	√
Can Tho DOT	O	O	O	O	⊗

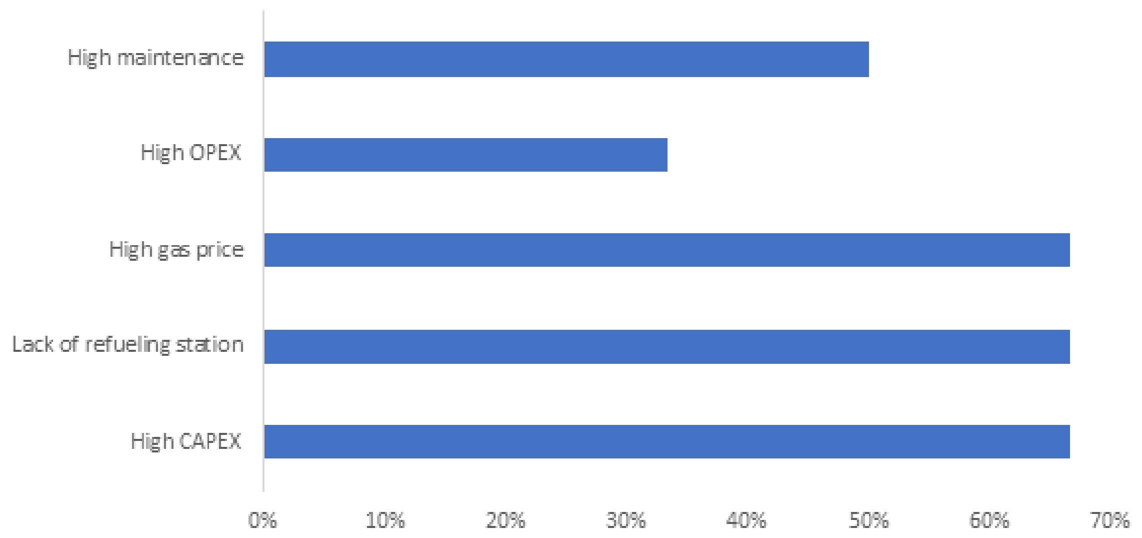
Source: Study team.

Note: O = No, ⊗ = Yes (not implemented), √ = Yes (implemented).

3.4.2 Demand for CNG buses from transport operators

Most transport operators are skeptical about using CNG buses. Perceived disadvantages are basically of a technical and financial nature, as can be seen in Figure 3.7.

FIGURE 3.7. **Perceived Disadvantages of CNG Buses**



Source: Customer survey by study team.

By far, the most mentioned barriers to the deployment of CNG buses are high investment costs, lack of refueling stations, and high gas prices. These are followed by high maintenance cost. While most companies mentioned being open to considering the purchase of a CNG bus, significant information effort is required to overcome the abovementioned barriers.

The survey reveals that the transport companies want to convert to NGVs if they receive incentives from the government or gas investors. Three assumptions are established for transport operators who are operating urban buses, including offering low interest rates for loans, supporting vehicle purchase cost, and subsidizing the operation costs. Following each assumption, the number of NGVs is mentioned in Table 3.13. There are different bright spots for NGVs in some cities. For example, a good market signal is seen for CNG buses in Hanoi and Binh Duong. Transport operators in both cities were willing to develop CNG buses even if they received relatively little financial support from the local government.

It is obvious that among the possible measures of market support aimed at a shift from using diesel vehicles to gas vehicles and proposed during the survey, the most effective are loan interest rate subsidies and supporting vehicle purchase cost. At the same time, transport operators require rather high values of such incentives, for example, more than 30 percent interest rate subsidies or more than 30 percent vehicle purchase cost. It is a fact that many transport operators worry about the risks of shifting to a new fuel source. They, therefore, need a financial guarantee to increase their beliefs in the new market.

TABLE 3.13. **Potential Demand for CNG Buses, Penetration Rate**

Parameter		Hanoi	Hai Phong	Da Nang	Ho Chi Minh City	Can Tho	Binh Duong
Offering low interest rates for loans	≥ 30% interest rate	50%–60%	10%–20%	40%–50%	40%–50%	10%–20%	50%–60%
	20%–29% interest rate	40%–50%	0	0	0	0	40%–50%
	10%–19% interest rate	30%–40%	0	0	0	0	30%–40%
	Less than 10% interest rate	10%–20%	0	0	0	0	10%–20%
Supporting vehicle purchase cost	> 30% CAPEX	70%–80%	10%–20%	40%–50%	40%–50%	10%–20%	
	20%–29% CAPEX	60%–70%	0	0	0	0	
	Less than 20% CAPEX	10%–20%	0	0	0	0	10%–20%
Subsidizing operation costs	Urban bus	10%–20%	10%–20%	40%–50%	100%	10%–20%	10%–20%

Source: Data processed from survey by study team.

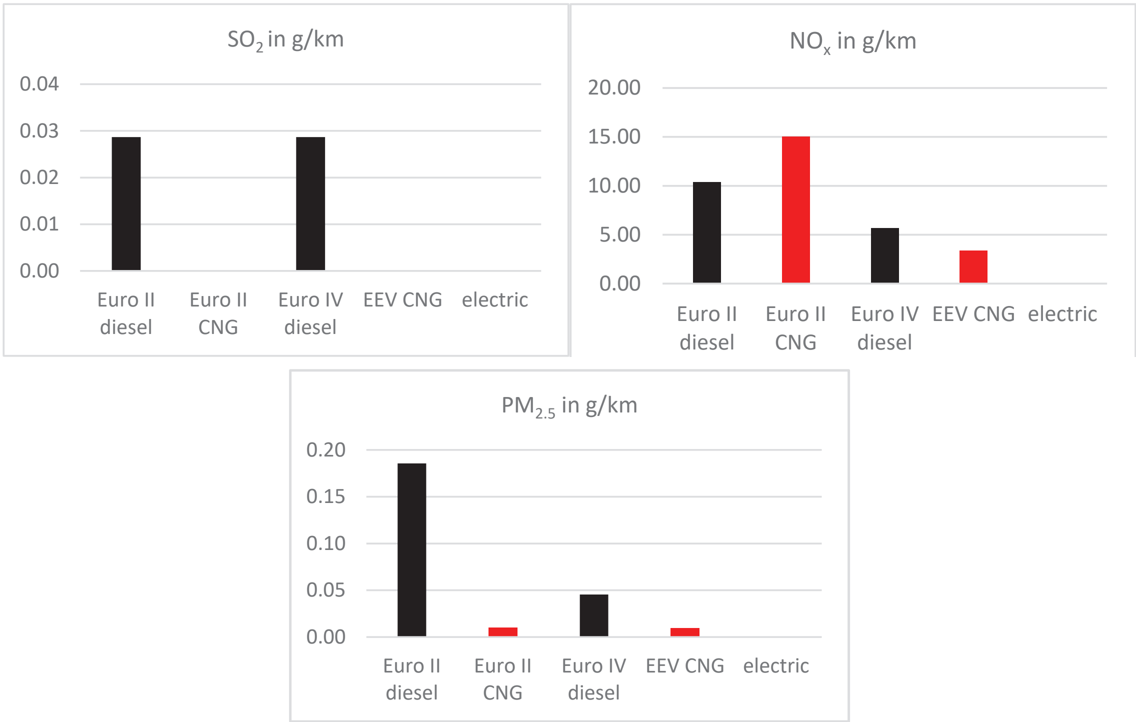
3.4.3 Advantages and disadvantages of CNG buses compared to conventional and electric buses

One of the important reasons to promote CNG buses is the contribution of these vehicles to the goal of reducing emissions (from the perspective of policy makers) or saving costs (from the perspective of transport operators). The analysis below compares the financial and environmental benefits of CNG buses compared to conventional and electric buses.

3.4.3.1 Environmental assessment of CNG buses

The following graphs show the environmental impact of different types of buses per bus-km. Euro IV (diesel) or Enhanced Environmentally Friendly Vehicle (EEV) (CNG) buses reduce emissions of critical pollutants (NO_x and $PM_{2.5}$) by 50% to 80%. Electric buses have zero combustion emissions and also do not deteriorate over time. The following graph compares GHG emissions of different bus types used in Ho Chi Minh City, i.e., all data is localized.

FIGURE 3.8. **Emissions of Pollutants from 8-Meter Urban Buses**



Source: Grütter Consulting 2019.

The following conclusions are made comparing GHG emissions of bus types in Ho Chi Minh City:

CNG buses have lower PM2.5 emissions than diesel units but still have very high NOx emissions (higher than those of diesel buses). Many cities worldwide have a major air quality problem—NOx emission causing ground-level ozone formation with severe health problems. E-buses produce zero local emissions and thus offer an effective strategy to combat air pollution.

E-buses in have 50 percent lower GHG emissions (well-to-wheel, including black carbon) than diesel Euro IV buses and 70 percent lower emissions than EEV CNG buses. They are, therefore, clearly an effective means to reduce GHG emissions from the transport sector. Emissions resulting from battery manufacturing for e-buses represent 2 percent to 5 percent of total GHG emissions from e-buses (the variance is due to different battery sets for e-buses depending on the technology chosen), i.e., the inclusion of battery manufacturing emissions does not significantly change the GHG reduction potential of e-buses.

3.4.3.2 Financial assessment of CNG buses

Results presented in the table and the graph below show that CNG buses have 10 percent higher total cost of ownership (TCO) than fast-charged battery electric bus (BEB). They have a higher capital expenmditure (CAPEX) compared to the diesel bus. This may be the reason why bus operators are reluctant to support CNG buses without financial support from the city government.

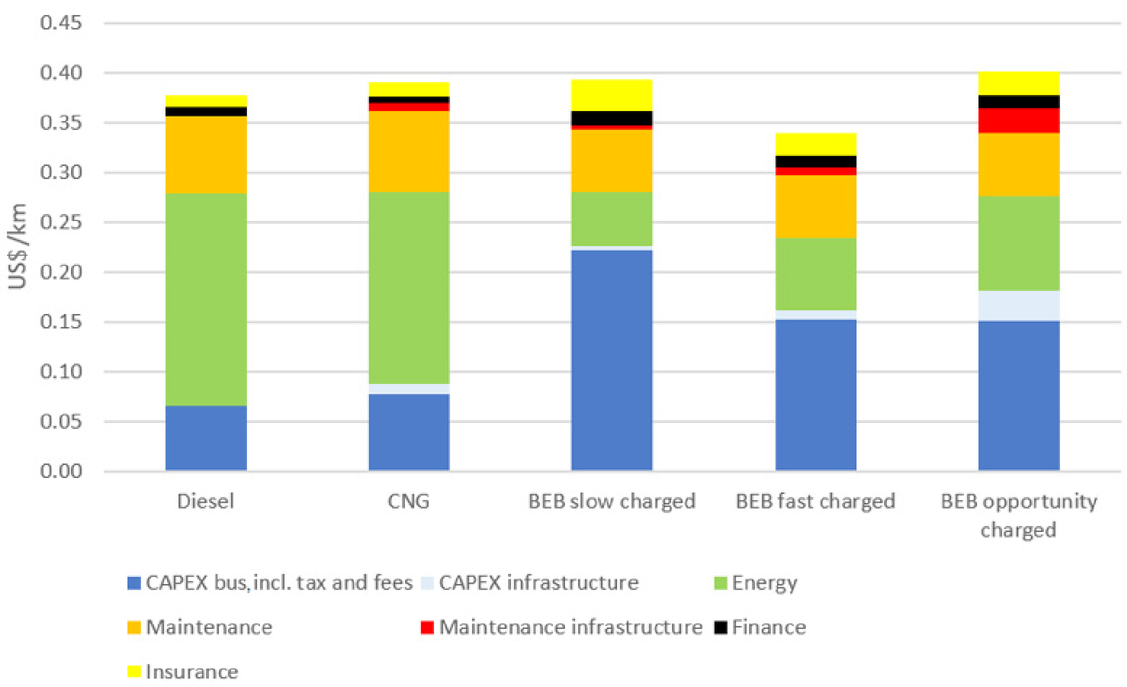
Table 3.14. Financial Results for Medium-Sized (8 meters) Buses

Parameter	Diesel Euro IV Bus	CNG EEV Bus	BEB Slow Charged	BEB Fast Charged	BEB Opportunity Charged
CAPEX bus	67,000	81,000	190,000	140,000	140,000
Tax and registration fee	1,340	0	9,500	7,000	7,000
CAPEX infrastructure per bus	0	11,000	5,000	9,530	32,500
Replacement cost of batterya	0	0	31,230	12,000	9,600
Energy cost per annum	13,830	12,430	3,460	4,680	6,150
Maintenance cost bus per annum	5,110	5,310	4,090	4,090	4,090
Maintenance infrastructure per annum	0	550	250	480	1,630
Insurance average per annum	730	880	2,070	1,530	1,530
Finance cost average per annum	560	440	980	750	860
TCO per km	0.38	0.39	0.39	0.34	0.40

Source: Grütter Consulting 2019.

Note: Maintenance infrastructure is 5 percent of CAPEX per annum. a: in year 8. Data presented in US$.

FIGURE 3.9. **Total Cost of Ownership of Medium Buses**



Source: Grütter Consulting 2019.

For large buses, the results are similar. TCO of CNG buses is equivalent to diesel buses and fast-charged BEBs but lower than slow-charged BEBs.

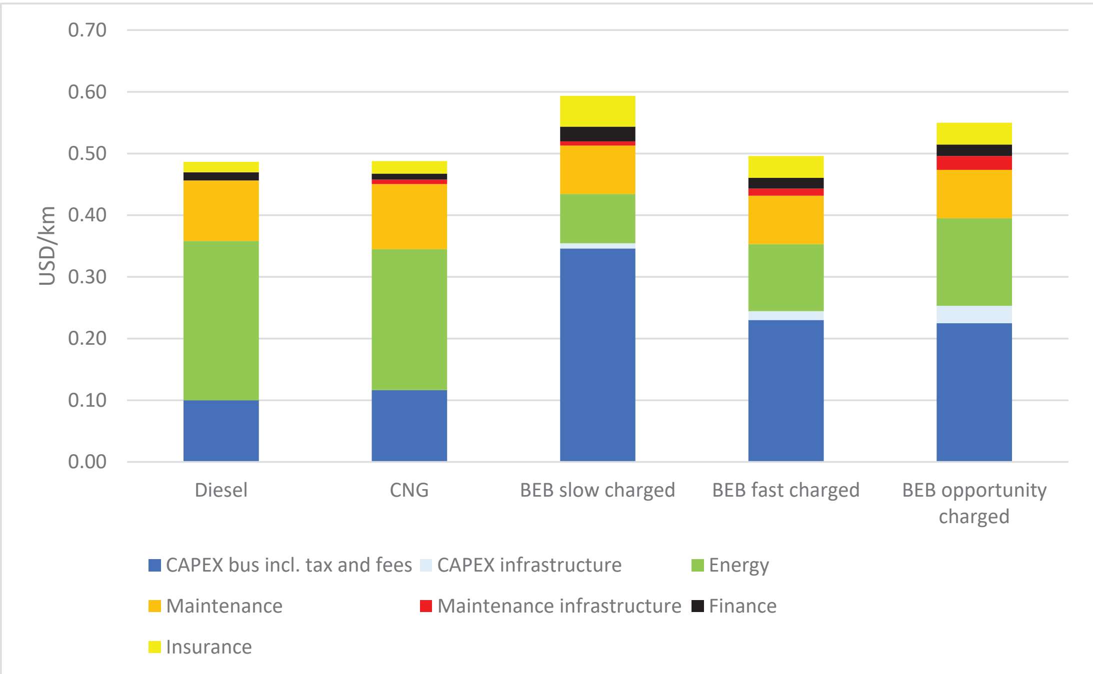
TABLE 3.15. **Financial Results for Large-Sized (12 meters) Buses**

Parameter	Diesel Euro IV Bus	CNG EEV Bus	BEB Slow Charged	BEB Fast Charged	BEB Opportunity Charged
CAPEX bus	116,000	138,000	340,000	240,000	240,000
Tax and registration fee	2,320	0	17,000	12,000	12,000
CAPEX infrastructure per bus	0	11,000	10,000	16,950	33,330
Replacement cost of batterya	0	0	52,800	20,400	14,400
Energy cost per annum	19,120	16,890	5,910	8,050	10,500
Maintenance cost bus per annum	7,260	7,810	5,810	5,810	5,810
Maintenance infrastructure per annum	0	550	500	850	1,670
Insurance average per annum	1,260	1,500	3,700	2,610	2,610
Finance cost average per annum	970	720	1,770	1,290	1,370
TCO per km	0.49	0.50	0.59	0.50	0.55

Source: Grütter Consulting 2019.

Note: Maintenance infrastructure is 5 percent of CAPEX per annum. a: in year 8. Data presented in US$.

FIGURE 3.10. **Total Cost of Ownership of Large Buses**



Source: Grütter Consulting 2019.

3.4.4 Scenario recommendation

3.4.4.1 CNG bus development scenario for the period from 2021 to 2030

From the above analysis, it can be seen that although the expectation of the policy makers and transport authorities in the development of CNG buses are considerable in the period from 2021 to 2030, some cities expect that 5 percent to 20 percent of buses will use low-carbon fuel. However, the lack of clarity on supporting policies and the low public transport share will prevent the achievement of this target. In addition, the attention of policy makers is now much toward e-buses. For instance, the Ministry of Transport (MOT) sent Official Dispatch No. 10250/BGTVT-VT to the People's Committees of Hanoi and Ho Chi Minh City on the operation of e-buses, emphasizing that the development of e-buses is consistent with the transport orientation and strategy of Vietnam.

Currently, the policy incentives for CNG bus development are slightly different compared to conventional buses. Enterprises investing in CNG buses in Ho Chi Minh City enjoy an additional 2 percent interest rate difference on preferential loans (transport operators with diesel buses will pay 5 percent loan interest for investing vehicle while transport operators with CNG buses will pay 3 percent loan interest in the same period). However, the support for the cost of operating CNG buses is not significantly different from that for diesel buses. Furthermore, CNG buses are also facing the limitation of refueling stations, high gas prices, and high maintenance costs.

Based on policy review and stakeholder consultations in five cities and one province, the number of CNG buses is forecasted in Hanoi, Hai Phong, Da Nang, Ho Chi Minh City, Binh Duong, and Can Tho. Currently, the total bus fleet in these five cities and one province accounts for about 36 percent of the total bus fleet nationwide. However, only two of the five cities and one province operate CNG buses: Ho Chi Minh City (495 units), Hanoi (129 units), and Binh Duong (84 units). In fact, the potential market of CNG buses is also concentrated in these five cities and one province. Based on the survey results to find out the willingness of transport operators to switch from diesel to CNG, the proportion of CNG buses is calculated for each city as follows:

TABLE 3.16. **Projection of CNG Buses in Five Cities and One Province in Vietnam**

City/Province	2020 (units)	2025 (units)	2030 (units)
Ho Chi Minh City (city)	496	910	1,430
Hanoi (city)	121	387	601
Hai Phong (city)	0	7	14
Binh Duong (province)	55	121	122
Da Nang (city)	0	7	18
Can Tho (city)	0	4	14
Total	672	1,435	2,199

Source: Study team.

Results from the interviews show that the number of CNG buses in Vietnam may reach 1,435 units by 2025 and 2,200 in 2030.

TABLE 3.17. **Development of CNG Buses versus Updated NDC**

Measures	Assumption in This Study	Assumption in Updated NDC
E20 - Promotion of CNG buses in transportation	By 2025, the number of CNG buses will reach 1,435 units By 2030, the number of CNG buses will reach 2,200 units	By 2030, the number of CNG buses will reach 623 units, including 423 in Ho Chi Minh City and 200 in Hanoi

Source: Study team.

3.4.4.2 Supportive policies to implement the scenario

Table 3.18 highlights the key economic and information instruments for the promotion of CNG buses. These instruments are outlined to provide information on the incentives available to support private investment in both vehicle fleet and refueling stations and to show whether they are targeted at public transport subsectors.

TABLE 3.18. **Supportive Policy Tools**

Economic	• Bus operation subsidy • Fuel cost support (subsidies and efficiency upgrades) linked to CNG buses • Grants, tax exemption, and price support to CNG bus companies • Incentives for domestic and international investors in the expansion of the refueling station—corporate income tax exemptions and preferenctial rates, import duty exemptions (for first-time imports of equipment and facilities for the development of public transport), land rental exemptions and reductions, accelerated depreciation of fixed assets
Information	• Clean-energy vehicle planning and refueling infrastructure network development planing to 2030 and a vision to 2050 • List of investment projects in public transport

Source: Study team.

Bus operation subsidy: The existing bus tariff is too low for bus companies, especially CNG bus companies, to recoup their costs. Hence, the government should provide direct subsidies to the bus companies based on the number of passengers carried on certain routes. For the cities that already have a public transport subsidy policy, an increase in CNG bus subsidies for the first three years is needed to encourage them to enter the CNG bus market.

Fuel cost support: The government has already implemented subsidies for fossil fuels. The largest component of these subsidies is allocated to electricity, with a much smaller portion supporting transportation through consumer subsidies for gasoline and producer subsidies in the form of reduced import tariffs for petroleum products. To promote CNG buses, the government should provide the primary CNG subsidies to transport operators to increase their affordability in the context of rising energy prices and to support the transport of citizens. On the other hand, the government can reduce tariffs for gas suppliers who sell CNG to transport operators.

Tax exemptions and incentives: Tax deductions and exemptions are necessary to attract international and domestic investors to develop a refueling station network. For example, investments in refueling infrastructure could benefit from a five-year income tax holiday, in addition to general foreign direct investment (FDI) tax exemptions and reductions on corporate income tax, import duty, and land rental charges.

Grants and concessional loans: Part of the perceived private investment shortfall, particularly for transport infrastructure projects, owes to the long time periods over which private sectors need to wait to see profit from their investment. Therefore, the government should support interest rates on commercial loans for investment in cleaner technology buses and refueling infrastructure.

Guarantees: Loan guarantees have been made available to support the purchase of new buses for other investment by state-owned enterprise (SOE) (or join stock) bus companies.

Land incentives: Government support includes covering the costs of ground clearance and exemption from land-use levies. In general, investment in CNG bus infrastructure should be considered as an investment-incentive sector and exempted from land-use fees. These exemptions also apply to pilot public-private partnership (PPP) initiatives.

Infrastructure planning: The MOT or DOTs should be responsible for forming clean-energy vehicle development planning while the MOIT coordinates with the MOT to establish the development plan of the refueling infrastructure network.

Investment and resource information: Based on the plans of clean-energy vehicles and refueling stations, the city government provides the basic information about services in the public transport, including a list of investment project opportunities to inform potential investors.

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NOTES

[1] Maximum annual capacity is calculated under the assumption that the facilities operate 20 hours a day, 360 days a year.

[2] Gazprom.

4. BAU Development

The business-as-usual (BAU) scenario is developed to forecast greenhouse gas (GHG) emissions based on statistics of transport activities and macroeconomic assumptions. The BAU scenario needs to be built on an appropriate model that has the ability to analyze in detail the activities of the transport sector in the bottom-up direction, examining the effects of policies on GHG emissions.

This project inherits the BAU scenario used to calculate the transport sector's contribution in the updated Vietnam's Nationally Determined Contribution (NDC) report. Some of the key outcomes of the BAU scenario will be presented in this part of the report.

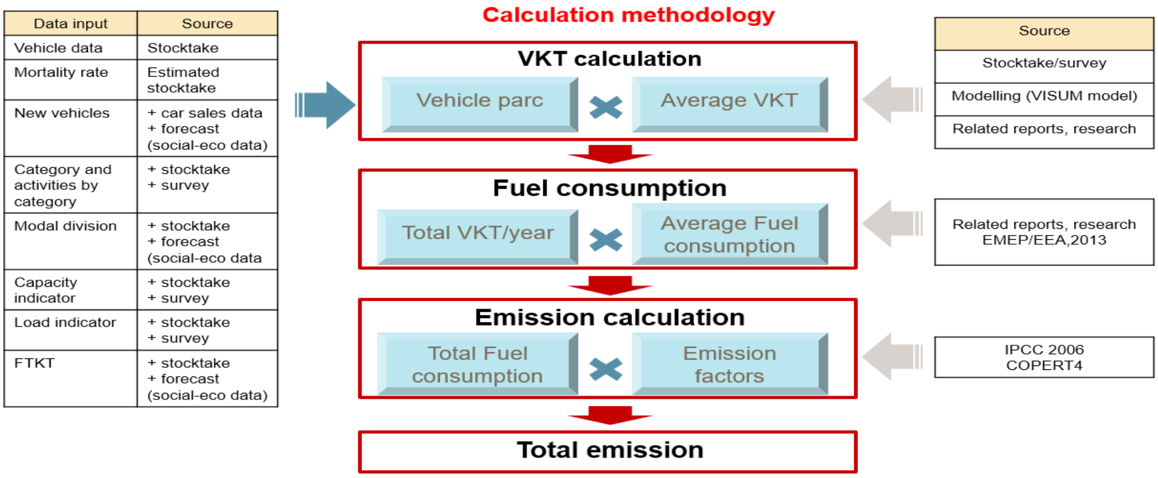
4.1 Methodology of BAU Development

The BAU scenario, also known as the "normal scenario," "baseline scenario," or "no mitigation scenario," is developed as a basis for calculating the emissions reduction potential of the measures in the transport sector. This scenario includes only measures adopted and implemented before 2020, which is considered a less ambitious scenario.

In addition to current measures, the BAU scenario also takes into account expected technological developments and socioeconomic development projections for the country (population, GDP, etc.). To ensure the comparability between the achievements of policy objectives, the assumptions and data sources used for the BAU in this study remain the same as those used for the BAU in the updated NDC 2020. The assumptions in the BAU scenario are shown in Appendix C of this report.

The calculation method of GHG emissions in the BAU scenario is summarized in the figure below.

FIGURE 4.1. **GHG Emissions Calculation Method in BAU**



Source: GIZ's 2018 Advancing Transport Climate Strategies Project.

4.2 Input Data of BAU Scenario

The input data of the BAU scenario is divided into five main categories: general data; road data; rail data; inland waterway, coastal data; and aviation data. These data are similar to Vietnam's updated 2020 NDC. As this study focuses on biofuel for road vehicles and CNG buses, only road data are mentioned.

TABLE 4.1. **General Data**

No.	Data	Source
1	GDP growth rate	Resolution No. 142/2016/QH13 "The approval of revisions to the national power development plan from 2011 to 2020 with visions extended to 2030"
2	GDP of the transport subsectors (%)	General Statistics Office/Central Institute for Economic Management (GSO/CIEM) interpolates for 2020–30; 2030–40; 2040–50
3	Annual population growth rate	GSO website: https://www.gso.gov.vn/en/population
4	Share of urban and rural population (%)	GSO website: https://www.gso.gov.vn/en/population
5	Household size (urban and rural)	GSO 2010, 2014, and 2018
6	Price of gasoline and diesel (before blending)	Ministry of Industry and Trade of the Socialist Republic of Vietnam's (MOIT) website: http://minhbach.moit.gov.vn/?page=petroleum_define&key=petroleum_ketcau
7	Share of ethanol into gasoline and share of biodiesel into diesel (in the future)	Decision No. 53/2012/QĐ-TTg "Roadmap for Application of Ratios for Blending Biofuels with Conventional Fuels"
8	Fuel prices (blending)	MOIT's website: http://minhbach.moit.gov.vn/?page=petroleum_define&key=petroleum_ketcau

Source: Compiled by study team.

TABLE 4.2. **Road Data**

No.	Data	Source
1	Proportion of new sale vehicles [motorcycle, car, light vehicle commercial (LCV), heavy commercial vehicles (HCV)]	VAMA 2015–2017: http://vama.org.vn/vn/bao-cao-ban-hang.html (accessed July 10, 2018)
2	Proportion of motorcycle, car, LCV, and HCV	VAMA 2015–2017: http://vama.org.vn/vn/bao-cao-ban-hang.html (accessed July 10, 2018)
3	Age of 50% retirement	Decree No. 95/2009/NĐ-CP & Circular No. 21/2010/TT-BGTVT of MOT
4	Vehicle operation (km/year)	Vietnam Register (2017), car survey at register center
5	Fuel economy (L/km)	European Monitoring and Evaluation Programme/ European Environment Agency (EMEP/EEA)
6	Average trip length	Calculation by VISUM model for BRT and metro JICA 2015
7	Change of vehicle operation (% km/year)	Calculation by VISUM JICA 2015
8	Vehicle occupancy (passenger)	JICA (2015); vehicle axle loading survey by mobile weighing stations in Hai Phong 2015
9	Load factors (cargo)	Calculation by VISUM JICA 2015
10	Average speed (urban, rural, and highway)	Calculation by VISUM

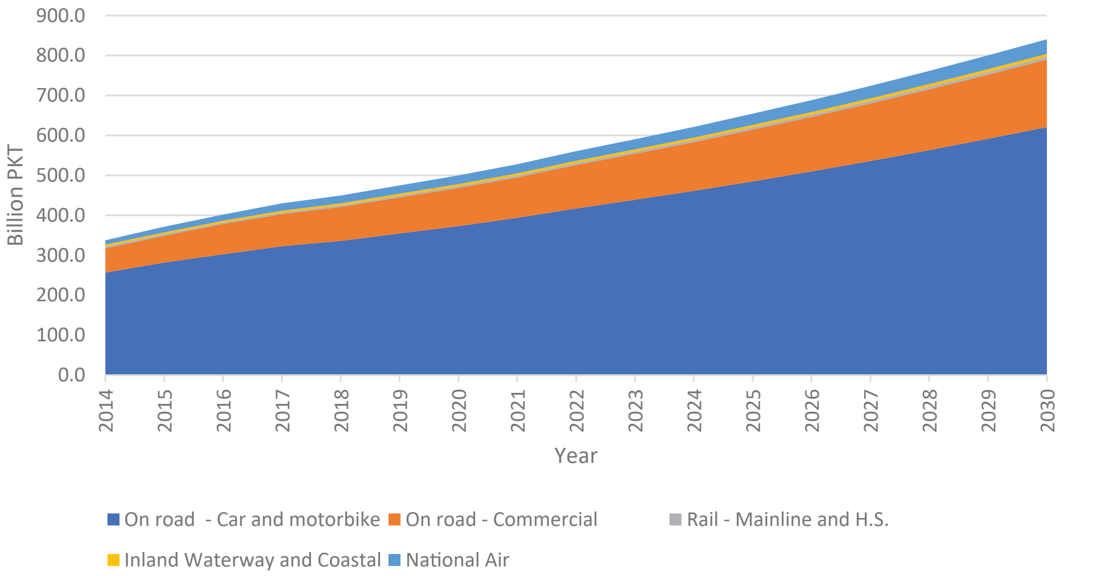
Source: Compiled study team.

4.3 Growth Projection in the Transport Sector Under BAU

4.3.1 Projection of passenger-kilometers traveled

As a consequence of the fast growth of the population and economies in Vietnam, passenger-kilometers traveled (PKT) will be about 840 billion by 2030. Seventy-five percent of passenger transport is by motorcycles and cars, while other road vehicles account for nearly 20 percent. Other subsectors, including railways, inland waterways, and aviation, account for only about 5 percent.

FIGURE 4.2. **Passenger-Kilometers Travelled (PKT) in Vietnam**

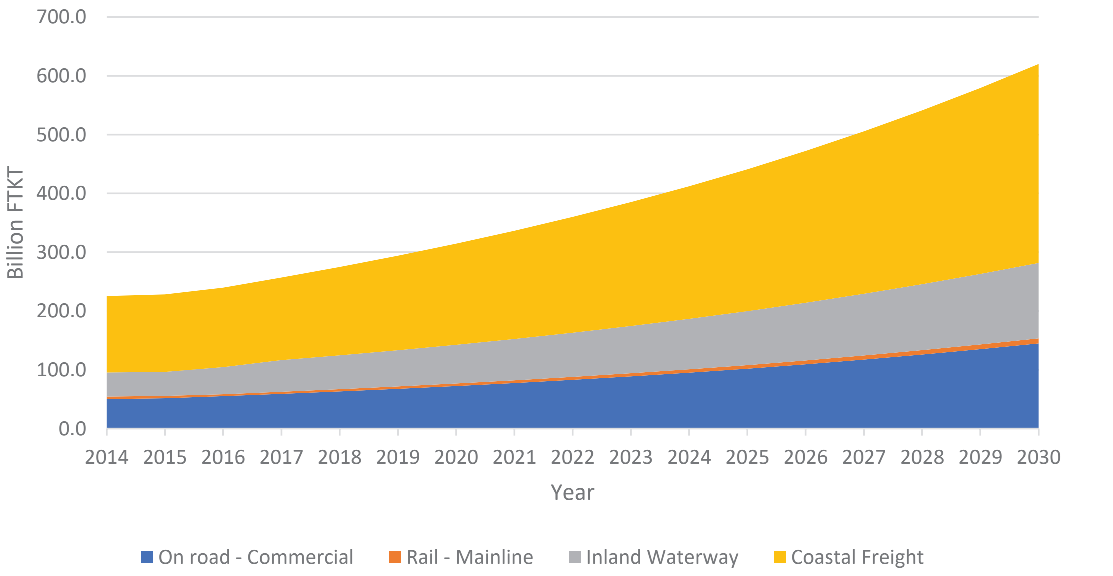


Source: Oh et al. 2019.

4.3.2 Projection of freight-ton-kilometers transported

Freight-ton-kilometers transported (FTKT) by sea accounts for the most significant proportion, with more than 55 percent of the total nationwide FTKT. Next is the FTKT by road and inland waterway with the rate of 23 percent and 20 percent, respectively. The volume of freight movement by rail accounts for only about 1.5 percent.

Figure 4.3. Freight-Ton-Kilometers Transported (FTKT) in Vietnam

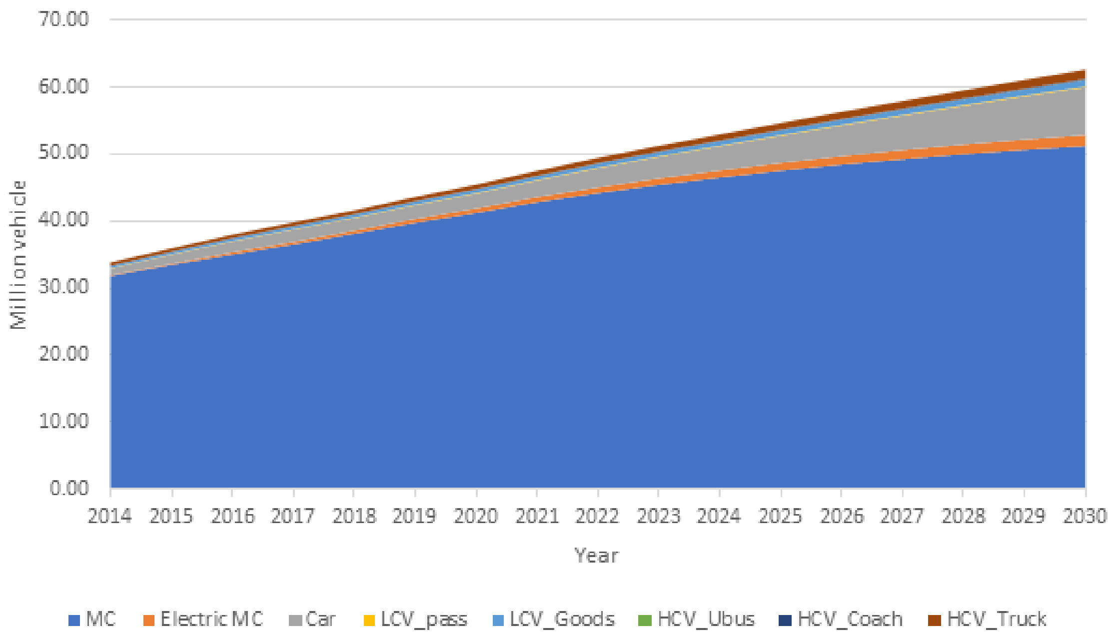


Source: Oh et al. 2019.

4.4 Total Road Vehicles

Road vehicles will be most affected by biofuel policies. The promotion CNG buses will only affect public transport by bus.

FIGURE 4.4. **Total Vehicles in Road Transport in Vietnam**



Source: Oh et al. 2019.

Motorcycles and cars account for more than 95 percent of the total number of road transport vehicles in Vietnam. These are also two types of vehicles that mainly use biofuels, so emissions are expected to decrease significantly.

The remaining vehicles, such as electric motorcycles, coaches, buses, and trucks, account for only 5 percent of the vehicle fleet.

4.5 Fuel Consumption

4.5.1 Total fuel consumption

Consumption of Fuel Oil (FO) has been almost constant over the years. Due to the characteristics of coastal transport, the number of vessels has not grown rapidly but only just enough to meet the demand for cargo and passenger transport. In contrast, gasoline and diesel oil consumption have experienced a high growth rate in response to the explosion in the number of road vehicles.

Jet kerosene is a fuel specifically for air transport, and it grows with the development of this subsector.

TABLE 4.3. **Total Fuel Consumption in Vietnam**

	2014	2020	2025	2030
Gasoline	4,596.2	6,660.2	8,813.8	11,655.1
Diesel	5,292.1	7,294.6	10,393.6	14,777.7
Fuel Oil	234.0	236.3	296.3	398.9
Jet Kerosene	1,699.4	3,298.3	4,137.4	5,110.0

Source: Oh et al. 2019.

Note: Data presented in thousand tons.

4.5.2 Gasoline consumption by road vehicles

In road transport, motorcycles and cars are the two main types of vehicles that consume gasoline. In 2014, gasoline consumption by motorcycles accounted for about 75 percent, and that of cars accounted for about 20 percent of total gasoline consumption in Vietnam's transport sector. The ratio of gasoline consumption by motorcycles and cars would be almost 50:50 by 2030.

LCV for transporting passengers (LCV_pass) and LCV for transporting goods (LCV_goods) using gasoline are declining. By 2030, the rate of these two types of vehicles using gasoline would be almost zero percent. Most of them would switch to using diesel.

TABLE 4.4. **Gasoline Consumption by Road Vehicles in Vietnam**

	2014	2020	2025	2030
Motorcycle	3,437.8	4,565.4	5,332.8	5,789.6
Car	910.8	1,976.3	3,442.5	5,862.0
LCV_pass	46.3	9.7	0.1	0.0
LCV_goods	201.3	108.8	38.5	3.6
Total	4,596.2	6,660.2	8,813.8	11,655.1

Source: Oh et al. 2019.

Note: Data presented in thousand tons.

TABLE 4.5. **Share of Gasoline Consumption by Road Vehicles in Vietnam**

	2014	2020	2025	2030
Motorcycle	74.8%	68.5%	60.5%	49.7%
Car	19.8%	29.7%	39.1%	50.3%
LCV_pass	1.0%	0.1%	0.0%	0.0%
LCV_goods	4.4%	1.6%	0.4%	0.0%
Total	100%	100%	100%	100%

Source: Oh et al. 2019.

4.5.3 Diesel consumption by road vehicles

Large trucks consume the most diesel among road vehicles, with about 68 percent in 2014 and decreasing to 56 percent in 2030. Second to trucks are coaches, with a rate of diesel consumption that is between 13 percent and 16 percent.

Cars, LCV_pass, and LCV_goods tend to increase the proportion of diesel fuel consumed. The most substantial increase is in cars, increasing five times from 2 percent in 2014 to 10.6 percent in 2030.

Buses account for about 5 percent of total diesel consumption. Buses are gradually being replaced by more modern, greener vehicles. Specifically, the Vietnamese government has many policies in place to promote the shift to buses that run on cleaner fuels such as CNG and electricity. The impacts of switching to CNG buses will be discussed in later chapters of this report.

TABLE 4.6. **Diesel Consumption by Road Vehicles in Vietnam**

	2014	2020	2025	2030
Car	74.6	248.3	567.0	1,179.2
LCV_pass	72.8	153.1	206.5	266.0
LCV_goods	270.2	625.9	960.0	1,382.6
HCV_Ubus	218.8	312.8	411.0	530.8
HCV_Coach	555.9	862.2	1,155.8	1,508.8
HCV_Truck	2,560.2	3,133.4	4,423.3	6,224.3
Total	3,752.6	5,335.8	7,723.7	11,091.6

Source: Oh et al. 2019.

Note: Data presented in thousand tons.

TABLE 4.7. **Share of Diesel Consumption by Road Vehicles in Vietnam**

	2014	**2020**	**2025**	**2030**
Car	2.0%	4.7%	7.3%	10.6%
LCV_pass	1.9%	2.9%	2.7%	2.4%
LCV_goods	7.2%	11.7%	12.4%	12.5%
HCV_Ubus	5.8%	5.9%	5.3%	4.8%
HCV_Coach	14.8%	16.2%	15.0%	13.6%
HCV_Truck	68.2%	58.7%	57.3%	56.1%
Total	100%	100%	100%	100%

Source: Oh et al. 2019.

4.6 CO_2 Emissions from Road Transport

Total CO_2 emissions from road transport are summarized in the following table.

TABLE 4.8. **CO_2 Emissions from Road Transport in Vietnam**

	2014	2020	2025	2030
Motorcycle	10,943.8	14,533.3	16,976.2	18,430.2
Electric MC	10.4	58.5	112.4	149.3
Car	3,133.3	7,070.1	12,737.6	22,360.3
LCV_pass	375.7	511.4	648.2	834.5
LCV_goods	1,488.7	2,310.4	3,134.8	4,349.4
HCV_Ubus	686.6	981.5	1,289.5	1,665.5
HCV_Coach	1,744.1	2,705.1	3,626.5	4,734.1
HCV_Truck	8,032.9	9,831.4	13,878.4	19,529.3
Total	26,415.6	38,001.7	52,403.6	72,052.7

Source: Oh et al. 2019.

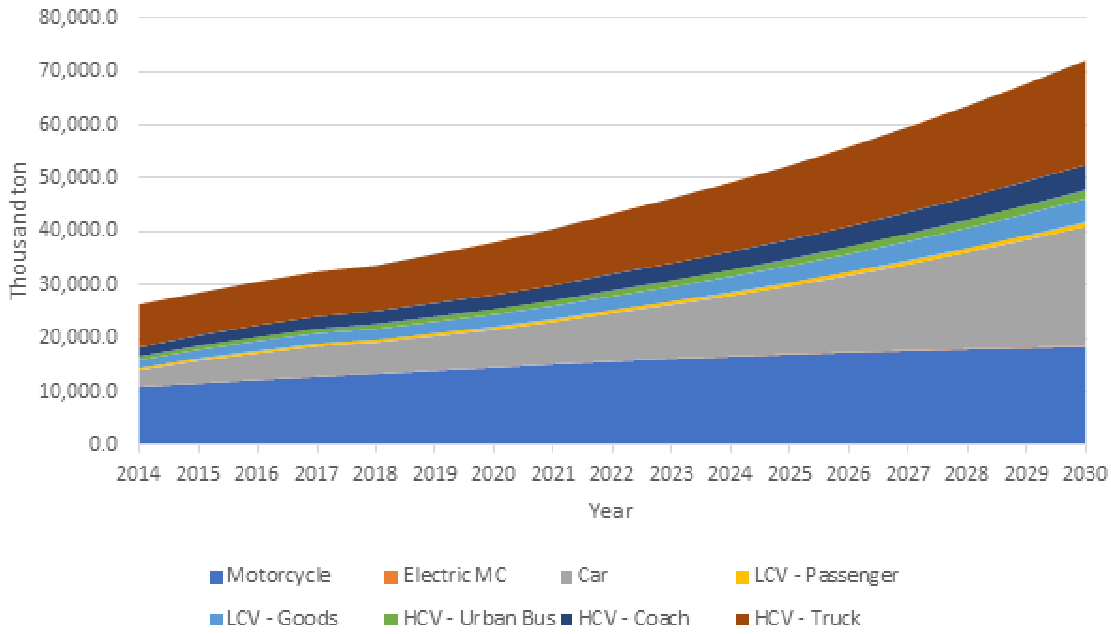
Note: Data presented in thousand tons.

TABLE 4.9. **Share of CO_2 Emissions from Road Transport in Vietnam**

	2014	2020	2025	2030
Motorcycle	41.4%	38.2%	32.4%	25.6%
Electric MC	0.0%	0.2%	0.2%	0.2%
Car	11.9%	18.6%	24.3%	31.0%
LCV_pass	1.4%	1.3%	1.2%	1.2%
LCV_goods	5.6%	6.1%	6.0%	6.0%
HCV_Ubus	2.6%	2.6%	2.5%	2.3%
HCV_Coach	6.6%	7.1%	6.9%	6.6%
HCV_Truck	30.4%	25.9%	26.5%	27.1%
Total	100%	100%	100%	100%

Source: Oh et al. 2019.

FIGURE 4.5. **CO_2 Emissions from Road Transport in Vietnam**



Source: Oh et al. 2019.

The tables and figures show that motorcycles and cars emit the highest levels of CO_2 in road transport. While the CO_2 emissions from motorcycles are projected to decrease from 41.4 percent in 2014 to 25.6 percent by 2030, the emissions from cars would increase from 12 percent in 2014 to 31 percent in 2030. This change can be explained by the trend of a reduction in motorcycles in the future in Vietnam.

In the BAU scenario, CO_2 emissions from urban buses account for 2.5 percent of total CO_2 emissions. Public transport is essential in urban transport, and the CO_2 emissions from the bus system are not too large. It is the reason why the Vietnamese government should promote the development of buses in the future. In addition, emissions from buses would be reduced if policies are in place to shift from conventional buses (diesel buses) to CNG buses or electric buses.

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5. Policy Scenarios and Road Maps for the Use of Biofuels in Vietnam

A moderate scenario for the use of biofuels would be developed based on the statistical results of biofuel consumption between 2015 and 2020, expert interviews, and surveys of ethanol and biogasoline producers implemented by study team. This scenario is called NDC-Deep Dive (NDC-DD scenario).

According to this scenario, the use of E5 gasoline tends to decrease slightly in the period from 2020 to 2024, from 38 percent in 2019 to 30 percent in 2024. By 2025, thanks to policy interventions, road vehicles will switch to using E10 gasoline at the rate of 15 percent by 2025 (the amount of ethanol is equivalent to 30 percent of E5 gasoline in 2024). After that, the rate of E10 gasoline will gradually increase and reach 30 percent in 2030. This E10 gasoline rate will also ensure biofuel production reaches 3.7 million tonnes of oil equivalent (TOE) by 2030, as mentioned in Decision 2068/QD-TTg.

TABLE 5.1. **Proportion of Biofuel in Road Transport in Vietnam**

Fuel Type	2020	2025	2030
E5	35%	0%	0%
E10	0%	15%	30%

Source: Study team.

5.1 Fuel Consumption

5.1.1 Gasoline consumption

Encouraging the use of biofuel, specifically E5 and E10 in this scenario, will reduce the consumption of conventional gasoline compared to the baseline scenario. This reduction is summarized in the following table.

TABLE 5.2. **Total Conventional Gasoline Consumption in Scenarios**

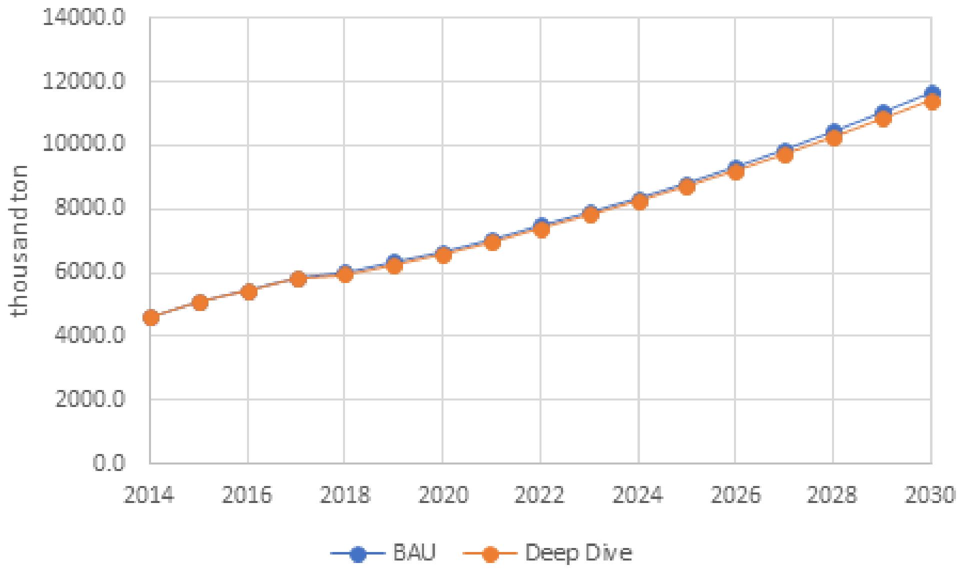
	2014	2020	2025	2030
BAU	4,596	6,660	8,814	11,655
NDC-NDC-DD scenario	4,596	6,583	8,727	11,423
Reduction of conventional gasoline consumption (compared to BAU)	-	77	87	232
Reduction rate of conventional gasoline consumption (compared to BAU)	0.0%	1.2%	1.0%	2.0%

Source: Study team.

Note: Data presented in thousand tons.

When applying the road map to encourage the use of biofuels mentioned in the scenario description, the consumption of conventional gasoline will decrease by 77,000 tons in 2020, which is about a 1.2 percent decrease compared to the baseline scenario. By 2030, with the switch to E10 gasoline, the consumption of conventional gasoline will be reduced by 232,000 tons, equivalent to 2 percent of the BAU scenario.

FIGURE 5.1. **Total Conventional Gasoline Consumption in Scenarios**



Source: Study team.

5.1.2 Ethanol consumption

Contrary to the reduction in the consumption of conventional gasoline, the amount of ethanol consumed would increase because it is used to mix with gasoline into biofuel. According to calculations, 128,500 tons of ethanol were needed in 2020 to produce biofuel for the transport sector. This figure will more than triple by 2030 to 387,200 tons of ethanol.

Based on the ethanol production capacity of domestic enterprises in the period from 2020 to 2030, the amount of ethanol needed for the transport sector can be fully met.

TABLE 5.3. **Total Ethanol Consumption**

	2014	2020	2025	2030
Ethanol (NDC-DD scenario)	0.0	128.5	145.6	387.2

Source: Study team.

Note: Data presented in thousand tons.

5.2 GHG Emissions

CO_2 emission of the scenarios are summarized in the following table.

TABLE 5.4. **CO_2 Emissions of the Scenarios**

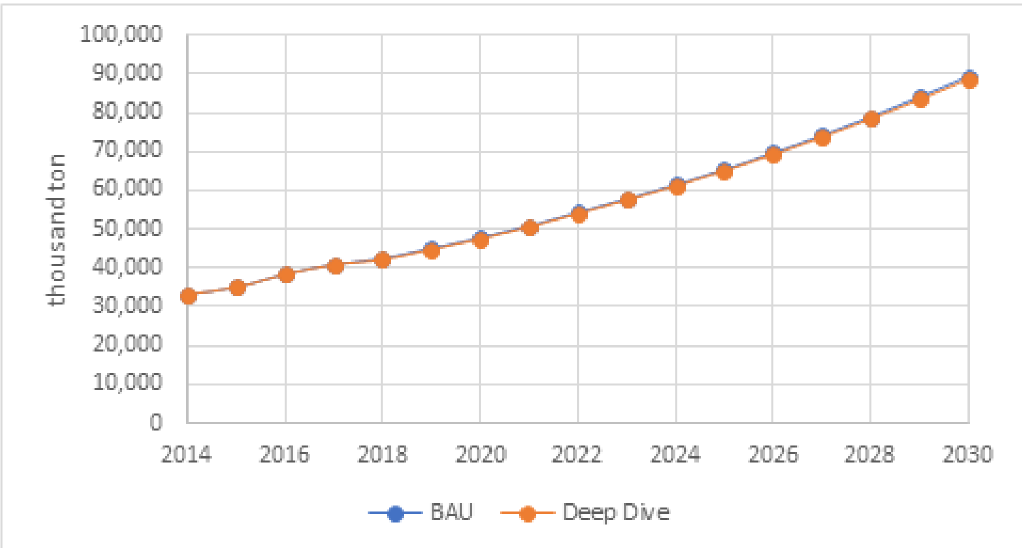
	2014	2020	2025	2030
BAU	26,416	38,002	52,404	72,053
NDC-DD scenario	26,416	37,757	52,126	71,315
Reduction of CO2 emissions	0	245	278	737
Reduction rate of CO2 emissions (compared to BAU)	0.00%	0.65%	0.53%	1.03%

Source: Study team.

Note: Only takes into account CO_2 emissions from road transport. Data presented in thousand tons.

Due to the reduction in the consumption of natural gasoline, CO_2 emissions from the biofuel incentive scenario are reduced compared to the baseline. This reduction is about 0.65 percent to 0.53 percent in the period from 2020 to 2025. When E10 gasoline has been put into use since 2025, the reduction will increase to about 1.03 percent, corresponding to a reduction of 737,000 tons of CO_2.

FIGURE 5.2. **CO_2 Emissions of the Scenarios**



Source: Study team.

5.3 Comparison between Biofuel Scenario of NDC 2020 and World Bank 2019 Report

The World Bank 2019 report by Oh et al. (2019) contributes to Nationally Determined Contribution (NDC) 2000 by selecting and prioritizing policies and measures that mitigate greenhouse gas (GHG) emissions from the transport sector. The activities and outputs in both reports under the scenario using only domestic resources are similar. These activities included the development of a scenario-based, bottom-up analysis of transport activities and resultant emissions from the base year of 2014 to 2030.

This section aims to identify appropriate deployment measures at the national and local levels using domestic resources, update the estimation of GHG emissions, and compares these results to the NDC 2020 and World Bank 2019 reports. The differences between the biofuel promotion scenario in this study and the one in the NDC 2020 (or World Bank 2019) are:

- NDC and World Bank 2019: limited supply of about 145,000 cubic meters (m^3) of ethanol per year between 2019 and 2030
- NDC Deep Dive study: no restriction on ethanol supply.

Thus, it can be seen that the scenario presented in this study will have higher efficiency in reducing emissions and natural gasoline consumption than the NDC 2020 update. The specific comparison results are summarized below.

5.3.1 Comparison with conventional gasoline and ethanol consumption

a. Conventional gasoline

The conventional gasoline consumption comparison between the BAU scenario, NDC scenario, and NDC-DD scenario is summarized in the following table.

TABLE 5.5. **Conventional Gasoline Consumption Comparison**

	2014	2020	2025	2030
BAU	4596.2	6660.2	8813.8	11655.1
NDC-DD scenario				
Natural gasoline consumption	4596.2	6583.3	8726.7	11423.5
Reduction rate (compared with BAU)	0.0%	1.2%	1.0%	2.0%
NDC scenario				
Natural gasoline consumption	4596.2	6579.5	8729.1	11571.0
Reduction rate (compared with BAU)	0.0%	1.2%	1.0%	0.7%

Source: Study team.

Note: Data presented in thousand tons.

The calculation shows that until 2025, the reduction of conventional gasoline consumption in the NDC-DD scenario is equivalent to the NDC 2020 and the World Bank 2019 report (Oh et al. 2019). However, with an introduction of E10 gasoline in the NDC-DD scenario after 2025, the reduction of conventional gasoline consumption would be up to 2 percent in the NDC-DD scenario, while the decrease in conventional gasoline consumption would be at 0.7 percent in the current NDC 2020.

b. Ethanol

The ethanol consumption comparison between the NDC scenario and the NDC-DD scenario is summarized in the following table.

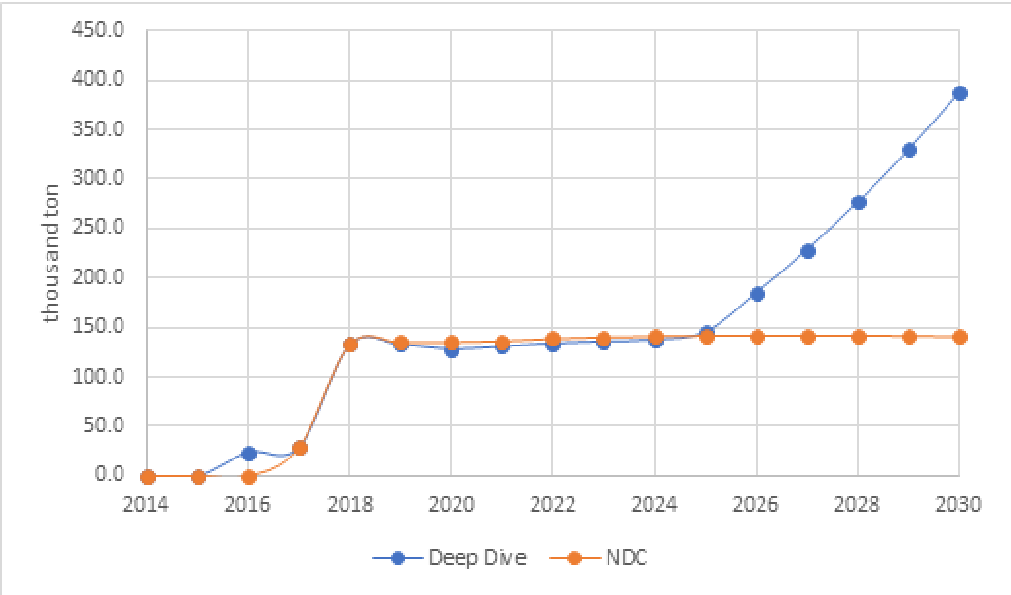
TABLE 5.6. **Ethanol Consumption Comparison**

	2014	2015	2016	2017
NDC-DD scenario	0.0	128.5	145.6	387.2
NDC scenario	0.0	134.9	141.6	140.6

Source: Study team.

Note: Data presented in thousand tons.

FIGURE 5.3. **Ethanol Consumption Comparison**



Source: Study team.

It can be seen that in the NDC 2020 update scenario [or the World Bank 2019 report (Oh et al. 2019)], ethanol demand for the transport sector is almost unchanged in the period from 2020 to 2030. Meanwhile, with the assumption in the NDC-DD scenario, ethanol demand will increase rapidly after 2025. However, this demand is still within the supply capacity of Vietnamese manufacturers.

5.3.2 Comparison of GHG emissions

The comparison of CO_2 emissions in the baseline scenario, the NDC scenario or World Bank 2019, and the NDC-DD scenario is summarized in the following table.

TABLE 5.7. **CO_2 Emissions Comparison**

	2014	2020	2025	2030
BAU	26,416	38,002	52,404	72,053
NDC-DD scenario				
CO2 emissions	26,416	37,757	52,126	71,315
Reduction rate (compared with BAU)	0.00%	0.65%	0.53%	1.03%
NDC scenario				
CO2 emissions	26,416	37,656	51,963	71,566
Reduction rate (compared with BAU)	0.00%	0.92%	0.85%	0.68%

Source: Study team.

Note: Only CO_2 emissions from road transport are taken into account. Data presented in thousand tons.

The comparison of CO_2 emissions reduction is quite similar to the decrease in conventional gasoline consumption. The NDC-DD scenario promotes higher emissions reduction potential in the period from 2025 to 2030.

5.4 Road Map for the Use of Biofuels in Vietnam

The key criteria of the NDC-DD scenario are summarized in Table 5.8. To meet such key criteria, a proposed road map is outlined in a set of relevant stakeholders' actions and measures by timeline (see Figure 5.4 and Figure 5.5).

TABLE 5.8. **Summary of the NDC-Deep Dive Scenario**

Criteria	2014	2020	2025	2030
Application of blending rates	5%	5%	10%	10%
Share of E5/E10 gasoline	0.0%	36.4%	15%	30%
Amount of dried cassava used for production of ethanol (thousand tons)	0	371	420	1,117
Amount of ethanol used for the blend (thousand m3)	0	163	184	490
Consumption of E5/E10 gasoline (thousand m3)	0	3,253	1,843	4,901

Source: Study team.

1. Finalization of Regulatory Framework: In the period from 2021 to 2024, the blending rate remains at 5 percent for RON92 gasoline (i.e., E5 RON92 gasoline) in accordance with Notification No. 255/TB-VPCP of the Government Office of Vietnam dated June 6, 2017. From 2025 to 2030, the blending rate will shift from 5 percent (E5 gasoline) to 10 percent (E10 gasoline). Hence, it is necessary to review and update the biofuel road map. Recommendations for actions and measures are as follows:

- **Review and Amendment of Biofuel Scheme No. 177 and Biofuel Road Map 53:** Specifically, the Department of Environment (DOE), Ministry of Transport (MOT), shall share the results of the World Bank's NDC-Deep Dive study with the Department of Science and

Technology (DOST), Ministry of Industry and Trade (MOIT). It is noted that the DOST (MOIT) is the focal point for the implementation of the biofuel road map in Vietnam. According to Directive No.11/CT-BCT of MOIT dated September 22, 2017, the DOST has been assigned to coordinate with line ministries, provinces, and relevant agencies for the implementation of biofuel road map in compliance with Decision No. 177/2007/QĐ-TTg (Biofuel Scheme No. 177) and Decision No. 53/2012/QD-TTg (Biofuel Road Map No. 53). Additionally, the DOST is responsible for review and amendment of these legal documents. Based on this, the MOIT will report to the prime minister of Vietnam for formulation and promulgation of a new biofuel scheme and road map.

- **Review and update of Vietnam's NDC post-2020 report:** In addition to the information exchanged with the DOST (MOIT), the DOE (MOT) shall share the results of the World Bank's NDC-Deep Dive study with the Department of Climate Change (DCC), Ministry of Natural Resources and Environment (MONRE). Since the DCC (MONRE) is the focal point for preparation and update of Vietnam's NDC reports, the NDC-DD scenario of biofuel development can be updated in subsequent NDC reports.

- **Review and update of draft action plans of the MOT for climate change and green growth:** The results of the World Bank's NDC-Deep Dive study should be integrated into the draft action plan of the MOT for climate change and green growth in the period from 2021 to 2030.

- **Review and amendment of national standards and technical regulations for biofuels:** The results of the World Bank's NDC-Deep Dive study should be shared with the Ministry of Science and Technology (MOST) because the MOST is responsible for formulation and promulgation of national standards and technical regulations for biofuels. On September 20, 2017, the MOST issued Decision No. 2548/QĐ-BKHCN on "Implementation Plan for Review and Amendment of National Standards and Technical Regulations for Biofuels." The information exchange between the MOT and the MOST may ensure that E10 gasoline is taken into account.

2. Feedstock supply: In the period from 2021 to 2024, cassava is still the primary feedstock for the production of ethanol in accordance with Decision No. 255/QĐ-TTg dated February 25, 2021, on "Approval of Restructuring Plan for Agricultural Sector in the Period of 2021-2025." According to this decision, cassava's volume and plantation area will remain at 10 million tons/year to 11 million tons/year and 500,000 hectares/year (ha/year), respectively. Based on the projected amount of ethanol in the NDC-DD scenario, the amount of dried cassava is estimated by using a conversion factor (2.28 tons of dry cassava chips produce 1 m^3 of ethanol).[1] As a result, the projected amount of cassava is 0.42 milion tons in 2025 and rises to 1.117 million tons in 2030. According to Vietnam Statistical Yearbooks, actual cassava's domestic volume and plantation area are in the range of 10 million tons/year to 11 million tons/year and 500,000–540,000 ha/year, respectively. Hence, feedstock supply is not a serious issue since domestic cassava supply exceeds demand, and dry cassava chips can be imported from other countries.

However, feedstock supply for the production of ethanol should not be dependent on only cassava. According to the survey of domestic ethanol producers, other types of feedstock can also be used for their current conversion technology, such as corn, sorghum, and sugarcane. Recommendations for actions and measures are as follows:

- **Development of alternative feedstock:** Alternative feedstock should be considered when the Restructuring Plan for the Agricultural Sector in the period from 2026 to 2030 and after 2030 is formulated by the Ministry of Agriculture and Rural Development (MARD). This plan will be a legal basis for the implementation of alternative feedstock supply in the period from 2026 to 2030.

- **Development of dedicated feedstock areas:** The formulation of a dedicated feedstock area scheme for domestic ethanol plants should be conducted by MOIT in cooperation with the MARD. This scheme will be a legal basis for the implementation of dedicated feedstock areas in the period from 2025 to 2030 period and after 2030.

3. Ethanol supply: According to the NDC-DD scenario, the ethanol demand for blending will be in the range of 160,000 m^3 and 180,000 m^3 in the period from 2021 to 2025. However, the amount of ethanol will be sharply increased in the period from 2026 to 2030 because of the shift from E5 gasoline to E10 gasoline. It will reach 490,000 m^3 by 2030. Currently, there are four domestic ethanol plants, but only two—both operated by Tung Lam Co. Ltd.—are in a stable operation with a total maximum capacity of 192,000 m^3 per year. Tentatively, there will be no issue for ethanol supply in the period from 2021 to 2025 since the production capacity of Tung Lam Co. Ltd. can cover the demand. However, an issue of ethanol supply may occur in the period from 2026 to 2030 due to the fast growth of ethanol demand.

In December 2019, the prime minister of Vietnam promulgated Decision No. 1743/QĐ-TTg on "Approval of Planning Tasks for National Energy Master Plan in the period of 2021-2030, Vision to 2050" (referred to as the National Energy Master Plan post-2020). Part of the overall objective of this decision is to ensure national energy security and mitigate climate change by promoting renewable energy. The MOIT prepared and submitted a draft final report of the National Energy Master Plan post-2020 to the government of Vietnam. According to this draft final report, it is projected that the volume of ethanol will increase from 268,690 m^3 in 2025 to 584,960 m^3 in 2030. Clearly, the ethanol demand in the NDC-DD scenario does not exceed planned ethanol supply in the draft of National Energy Master Plan post-2020. When the National Energy Master Plan post-2020 is approved, it will be the legal basis for the implementation of ethanol plants in the period from 2021 to 2030. Recommendations for actions and measures are as follows:

- **Support for reoperation of two ethanol plants:** Currently, there are two ethanol plants where opeations have been discontinous due to financial loss—one operated by Binh Son Biofuel and Petroleum Joint Stock Company (BSR-BF) in Quang Ngai province and the other by Phuong Dong Biofuels Company Ltd. (OBF) in Binh Phuoc province. Each ethanol plant has a maximum capacity of 100,000 m^3 per year. If both of them are stably operated, the total capacity of all domestic ethanol plants could be up to 400,000 m^3 per year. Therefore, MOIT, in cooperation with these ethanol producers, should restart the operation of these plants. Hence, it is necessary to provide loans with preferential interest rates.

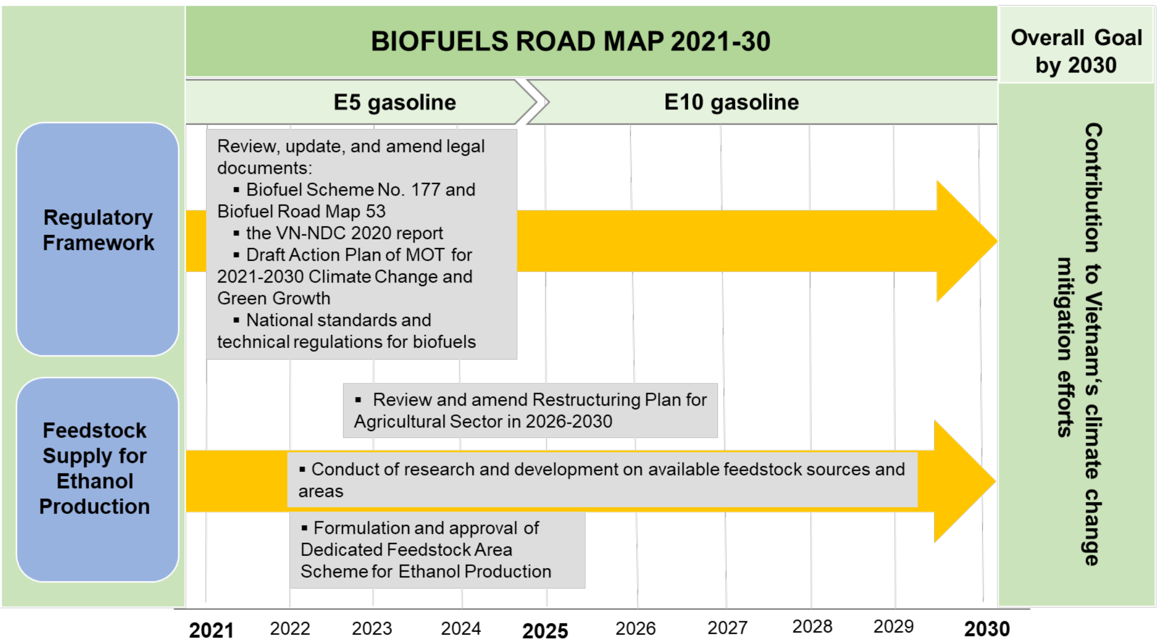
- **Construction of new ethanol plants:** Ethanol can be imported from other countries, but one or two new ethanol plants with a maximum capacity of 100,000 m^3 per year should be constructed in compliance with the National Energy Master Plan post-2020.

4. E10 gasoline supply and consumption: According to the NDC-DD scenario, the consumption of E5 gasoline will be in the range of 3.3 million m^3 (mcm) to 3.5 mcm in the period from 2021 to 2024. Because of the shift from E5 gasoline to E10 gasoline, the consumed amount of E10 gasoline will be 1.8 mcm in 2025, then it will reach 4.9 mcm in 2030. According to the survey of key suppliers of E5 gasoline, the total current capacity of blending systems is up to 4.3 mcm per year. Additionally, the report of the MOIT indicated that the capacity of key gasoline traders' blending systems can be expanded up to 6.2 mcm per year to 6.7 mcm per year (MOIT 2017). The supply side does not face any difficulties in the expansion of blending systems. However, there has been an issue on the demand side due to people's concerns about the quality of biogasoline. Recommendations for action and measures are as follows:

- **Maintenance and expansion of biogasoline distribution and production system:** In the period from 2021 to 2025, the MOIT should instruct key traders to retain the existing biogasoline distribution system, especially for blending systems and biogasoline pumps at gas stations. After 2025, the expansion of the distribution system should be studied and implemented when the demand increases.

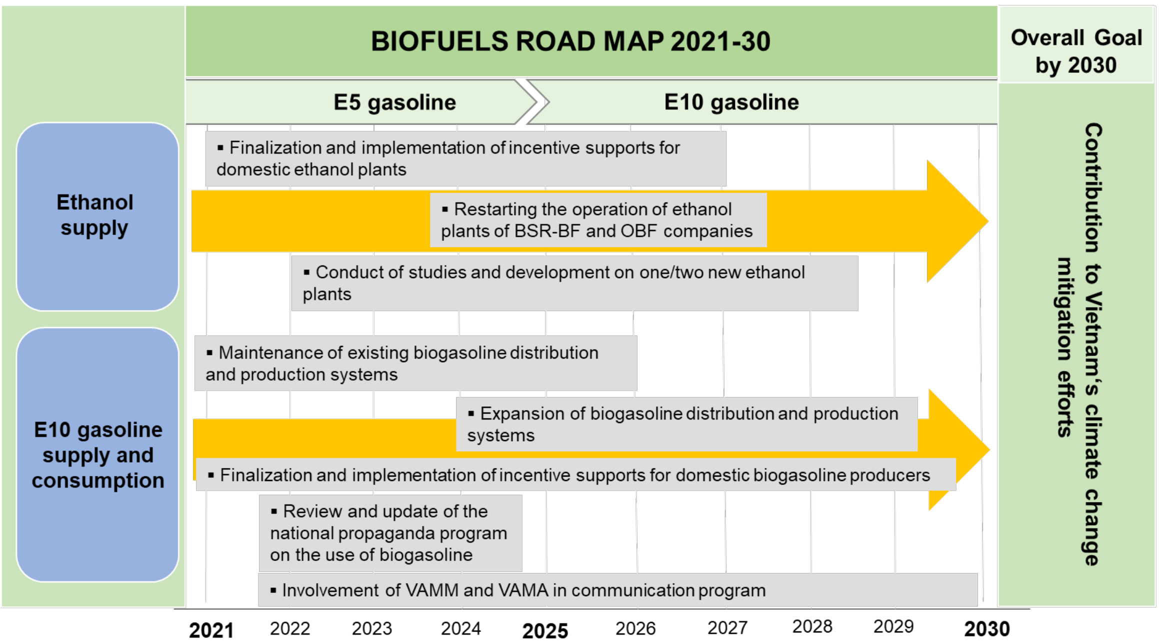
- **Reinforcement of propaganda program:** The Ministry of Information and Communication (MOIC) carried out the national communications program on the use of biofuels in the period from 2017 to 2020 in accordance with Decision No. 1622/QĐ-TTTT dated September 29, 2017. For the period from 2021 to 2030, a new national communications program should be formulated by the MOIC. As per the findings of the driver interview survey, a significant share of motorcycle and car drivers believe that biogasoline is harmful to the engine of their vehicles. Additionally, the survey result indicates that the confirmation from vehicle manufacturers that it is safe to use biogasoline in vehicles. In Vietnam, there are two vehicle manufacturer associations—Vietnam Automobile Manufacturers' Association (VAMA) and Vietnam Association of Motorcycle Manufacturers (VAMM). The involvement of VAMA and VAMM in the communications program may help people become more aware of the benefits of using biogasoline.

FIGURE 5.4. **Biofuels Road Map for the NDC-Deep Dive Scenario (Part I)**



Source: Study team.

FIGURE 5.5. **Biofuels Road Map for the NDC-Deep Dive Scenario (Part II)**



Source: Study team.

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NOTE

[1] Official Dispatch No. 12138/BTC-CST of Ministry of Finance.

6 Policy Scenarios and Road Maps for the Development of CNG Bus Fleets in Major Cities in Vietnam

6.1 Scenario Description

Based on the development orientation of compressed natrual gas (CNG) buses in the period from 2020 to 2030 and the results of the analysis of the development trend of natural gas vehicles (NGVs) in the period from 2020 to 2030, the research team has developed a scenario for the development of CNG buses in the major cities of Vietnam.

This is a rather moderate scenario, implying that the participants in the CNG bus market react moderately to changes in this market. Government support in this case is also minimal. It should be noted that the promotion of the use of CNG buses is carried out at the same time as the development of the public passenger transport system nationwide (mainly in central-affiliated cities and first-class urban centers).

In this scenario, the number of new CNG buses added to the bus vehicle fleet in the period from 2021 to 2025 is 727 vehicles and in the period from 2025 to 2030 is 764 vehicles.

TABLE 6.1. **CNG Bus Demand Scenario Description**

Support Measures Proposed by Fleet Operators	Market Growth Assumption	
	Vehicle Types	
	Parameters	
Support interest rates to invest in purchasing CNG buses and investing in building CNG filling stations	The number of CNG buses in 2025 is 1,435 vehicles and in 2030 is 2,199 vehicles	Determined by fleet operators in surveys and interviews
	Starting time	2021

Source: Study team.

6.2 Fuel Consumption

6.2.1 Diesel consumption

With the appearance of CNG buses, diesel consumption by public transport is reduced compared to the baseline scenario. Diesel consumption will decrease by about 3.7 percent in 2020. Consumption will continue to decline to 6.5 percent in 2025 and to 8.3 percent in 2030, corresponding to an increase in the number of CNG buses.

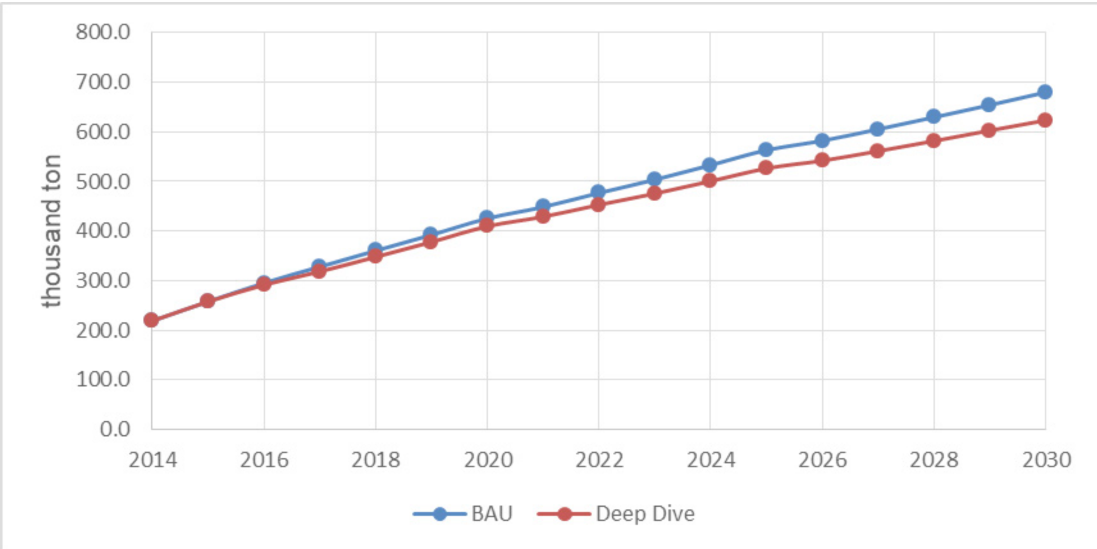
TABLE 6.2. **Diesel Consumption by Public Transport in Vietnam**

	2014	2020	2025	2030
BAU	218.8	425.5	563.3	680.0
CNG buses promotion scenario	218.8	409.7	526.5	623.5
Reduction rate of diesel consumption (%)	0.0%	3.7%	6.5%	8.3%

Source: Study team.

Note: Data presented in thousand tons.

FIGURE 6.1. **Diesel Consumption by Public Transport in Vietnam**



Source: Study team.

Note: Data presented in thousand tons.

6.2.2 CNG consumption

In contrast to diesel consumption, CNG consumption increases in proportion to the increase in the number of CNG buses in the fleet.

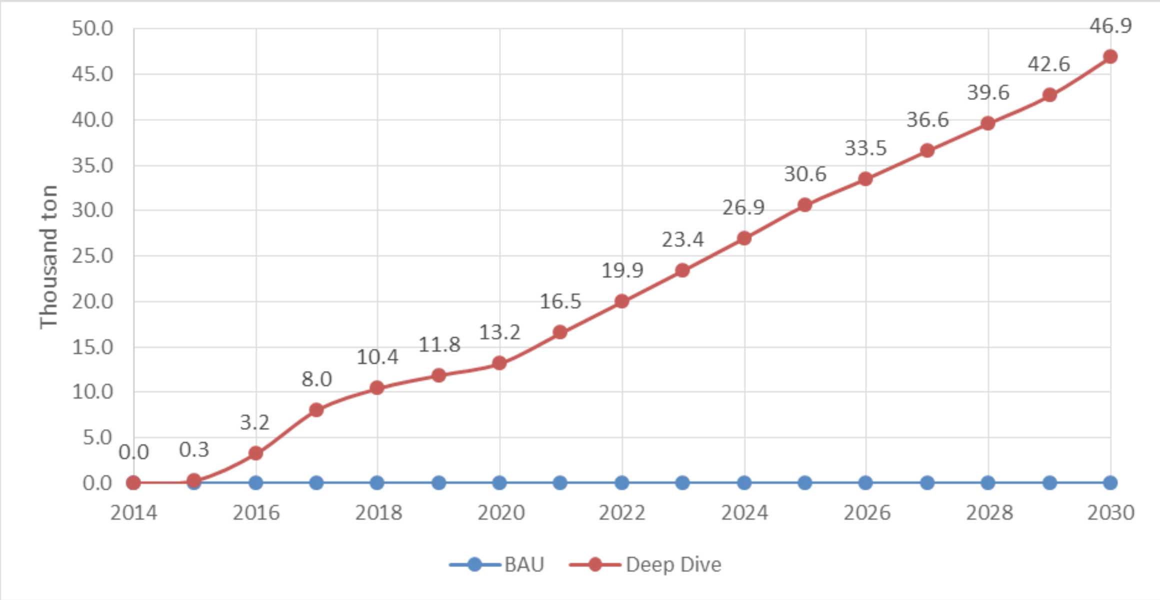
Table 6.3. CNG Consumption by Public Transport in Vietnam

	2014	2020	2025	2030
BAU	0.0	0.0	0.0	0.0
CNG buses promotion scenario	0.0	13.2	30.6	46.9

Source: Study team.

Note: Data presented in thousand tons.

FIGURE 6.2. **CNG Consumption by Public Transport in Vietnam**



Source: Study team.

6.3 GHG Emissions

Total CO_2 emissions from public transport in each scenario are summarized as following:

Table 6.4. Total CO_2 Emissions from Public Transport in Vietnam

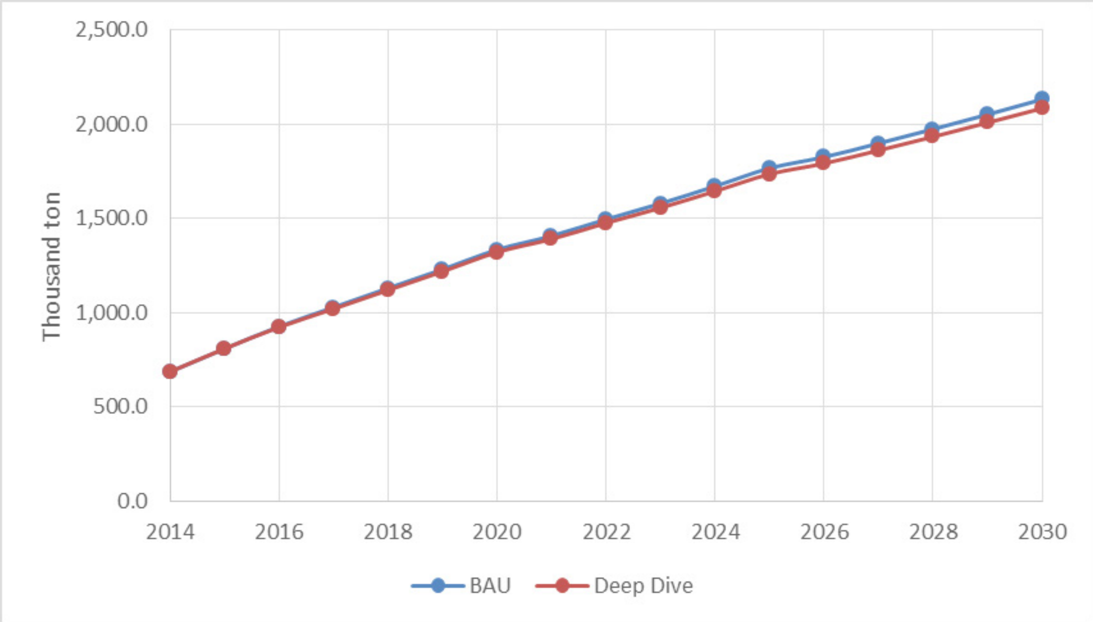
	2014	2020	2025	2030
BAU	686.6	1,334.9	1,767.4	2,133.5
CNG buses promotion scenario (NDC-DD scenario)	686.6	1,321.7	1,736.5	2,085.6
CO2 emissions reduction	0.0	13.3	30.9	47.9
Reduction rate of CO2 emissions (%)	0.0%	1.0%	1.8%	2.3%

Source: Study team.

Note: Only takes into account CO_2 emissions from buses in public transport. Data presented in thousand tons.

In 2020, CO_2 emissions will be reduced by 13,300 tons if the CNG bus incentive scenario is applied, equivalent to about 1 percent of CO_2 emissions from public transport by buses in the base scenario. By 2030, the emissions reduction rate of this scenario is about 2.3 percent. The absolute value is a reduction of 47,900 tons of CO_2, about 3.5 times more than the reduction in 2020.

FIGURE 6.3. **Total CO_2 Emissions from Public Transport in Vietnam**



Source: Study team.

6.4 Comparison of CNG Bus Promotion Scenario in NDC-Deep Dive and Vietnam's NDC Report 2020

The differences between the CNG bus promotion scenario in the NDC-Deep Dive study and the NDC report (or World Bank 2019) are:

- **NDC:** The number of CNG buses increased rapidly in the period from 2014 to 2020, then slowly increased and reached a total of about 623 CNG buses by 2030. (According to actual statistics in 2020, the total number of CNG buses is 687 vehicles, more than the target 623 vehicles by 2030 in NDC report 2020).

- In this study, the number of new CNG buses added to the bus fleet continues to increase in the period from 2020 to 2030. By 2030, the number of CNG buses will reach about 2,200 vehicles.

It is easy to see that the development of CNG buses in this study has a higher potential to reduce emissions and diesel fuel consumption than the option in the NDC scenario. However, it also requires investment in more CNG bus facilities. The specific comparison results are summarized below.

6.4.1 Comparison of diesel consumption

The comparison of diesel fuel consumption by bus fleet between the BAU scenario, the NDC-DD scenario, and NDC scenario (or World Bank scenario 1) is summarized in the following table:

TABLE 6.5. **Diesel Consumption of the Scenarios**

	2014	2020	2025	2030
BAU	218.8	425.5	563.3	680.0
NDC-DD scenario				
Diesel consumption	218.8	409.7	526.5	623.5
Reduction of diesel consumption (Compared with BAU)	0.0%	3.9%	7.0%	9.1%
NDC scenario				
Diesel consumption	218.8	409.7	551.9	674.7
Reduction of diesel consumption (Compared with BAU)	0.0%	3.9%	2.1%	0.8%

Source: Study team.

Note: Figures in the scenarios only take into account diesel consumption by buses in public transport. Data presented in thousand tons.

Under the NDC 2020 scenario (or World Bank 2019 scenario 1), there will be a total of 623 CNG buses in 2020, and this number will remain the same until 2030. In this scenario, diesel consumption is projected to decrease by 0.8 percent by 2030 in comparison to BAU.

In constrast, with an increase in the number of CNG buses in the NDC-DD scenario to 2,199 units, diesel consumption is projected to significantly decrease. By 2030, diesel consumption is projected to decrease by 9.1 percent in comparison to BAU.

6.4.2 Comparison of GHG emissions

The comparison of CO_2 emissions from bus vehicle fleet between the scenarios is summarized in the following table:

TABLE 6.6. **CO_2 Emissions in the Scenarios**

	2014	2020	2025	2030
BAU	686.6	1,334.9	1,767.4	2,133.5
NDC-DD scenario				
CO2 emissions	686.6	1,321.7	1,736.5	2,085.6
Reduction rate of CO2 emissions (compared with BAU)	0.0%	1.0%	1.8%	2.3%
NDC scenario				
CO2 emissions	686.6	1,321.7	1,757.9	2,129.2
Reduction rate of CO2 emissions (compared with BAU)	0.0%	1.0%	0.5%	0.2%

Source: Study team.

Note: Only takes into account CO_2 emissions from buses in public transport. Data presented in thousand tons.

Similar to the reduction of diesel fuel consumption, an increase in the number of CNG buses in the NDC-DD scenario results in a higher reduction of CO_2 emissions compared to the NDC 2000 (or World Bank 2019 scenario 1).

6.4.3 Comparison of the number of CNG buses

The total number of CNG buses in the scenarios is shown in the following table:

TABLE 6.7. **Number of CNG Buses in the Scenarios**

	2014	2020	2025	2030
Deep Dive	0	617	1,435	2,199
NDC	0	617	623	623

Source: Study team.

In the NDC scenario, the number of CNG buses remains at around 623 until 2030. Meanwhile, the number of CNG buses in the Deep Dive scenario continues to increase between 2020 and 2030—up from 1,435 vehicles in 2025 to 2,199 vehicles in 2030.

6.5 Road Map for the Development of CNG Bus Fleets in Vietnam

The proposed road map sets out an agenda of sector reforms and refuelling infrastructure that addresses the challenges described above and moves Vietnam's bus fleet toward becoming cleaner and more efficient. The reform measures are grouped into three categories:

Legal and regulatory framework: proposing policies, codes of practice needed to facilitate the transition to a liberalized market

Business structure: restructuring business functions in order to establish regulatory transparency and minimize conflict of interest

Gas price mechanism: development over time of gas price mechanisms that enable transport companies and gas providers to engage in trade that promotes a progressively higher portion of Vietnam's CNG bus fleet

Infrastructure: providing more station availability and increased dispensing efficiencies.

All four pathways work together to reduce criteria and GHG emissions, and improve the fuel efficiency of buses.

6.5.1 Period from 2021 to 2025

During the period from 2021 to 2025, the overall objective is to complete the changes to Vietnam's legal and regulatory framework necessary to support a competitive wholesale gas and transport market toward clean-energy vehicles. Key steps in this period include:

- The Ministry of Industry and Trade (MOIT), in line with relevant ministries, should issue a government circular on the development and promulgation of CNG market rules allowing flexibility in CNG supply contracting and reducing barriers for CNG trading.

- Issuance of a government resolution on the importance of clean vehicles and fueling infrastructure in helping Vietnam meet its transport energy diversification and air quality improvement goals. This will establish clearly the role that CNG buses (or other clean-energy vehicles) can and should play, as has been communicated about other alternative fuels and vehicles.

- Development and promulgation (in the form of a circular) of transport business rules providing financial incentives of CNG prices for transport companies

- Planning of clean-energy vehicles

- Setting up the requirements for purchasing clean-energy vehicles during the bidding process for new public transport routes

- Promulgation of regulations to encourage private investment in fueling infrastructure construction

- Further enhancements to the planning process for clean-energy vehicles to: use economic cost-benefit evaluations and least cost planning to determine investment priorities and enhance integration between CNG buses and electric buses.

6.5.2 Period from 2026 to 2030

With all of the preconditions for a competitive clean-energy vehicles market in place by 2026, the primary objective of the next five-year period is to bring 2,199 CNG buses into operation by 2030. Key actions in this period include:

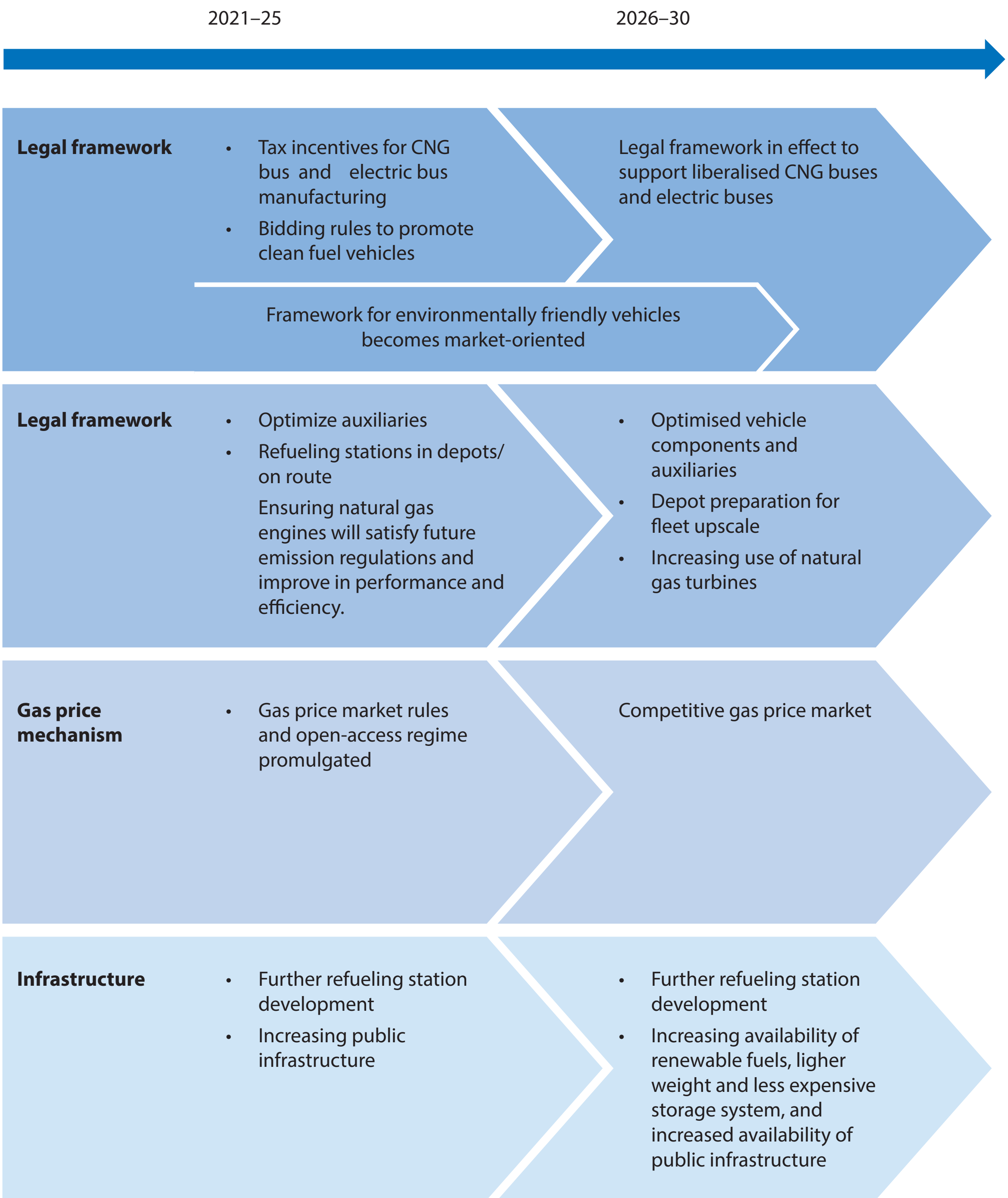
- Transport companies commence full operation of the CNG bus market based on established open access arrangements, new CNG price contracts, and modified legacy CNG price contracts

- Investments are made in the ICT systems and infrastructure necessary to support clean-energy vehicle market operations

- Transport authorities (Ministry of Transport or Departments of Transport) conduct a review of the clean-energy vehicle market at the national and city levels, including monitoring and reporting on the results of investment deployment and operation of clean-energy vehicles

- Further market-oriented revisions to the clean-energy vehicle planning framework.

FIGURE 6.4. **CNG Buses Road Map 2021–30**



Source: Study team.

7 Conclusions and Policy Recommendations

Biofuel and CNG buses have relatively low greenhouse gas (GHG) emissions reduction potential in the long term compared to the projected total GHG emissions from the transport sector under the business-as-usual (BAU) emissions scenario. Given Vietnam's current market, existing regulations, and industrial situation, both biofuel and CNG buses face challenges in penetrating the fuels and vehicles markets. Under the BAU scenario, both biofuel and CNG bus penetration is projected to have zero percent of market share until 2030.

On the one hand, it is assumed that the amount of E5 consumed is 2.9 million m^3 (mcm) per year in accordance with the government's committed policy—as per the report of Nationally Determined Contribution (NDC) 2020. Hence, the share of E5 will decline to 18 percent of the fuel mix by 2030 (i.e., low-penetration scenario). On the other hand, E10 is predicted to reach 30 percent of the fuel mix by 2030 in the medium-penetration scenario, according to the current government's planned policy (as per the draft of Vietnam Green Growth Strategy 2021–2030). Based on this study, there are several policy recommendations as follows:

- **Feedstock supply:** Alternative feedstock (e.g., corn) must be considered when demand for ethanol is increased. In existing policies, only cassava is selected as feedstock for the production of ethanol. It is necessary to formulate and promulgate policies regarding alternative feedstock for the production of ethanol in Vietnam.

- **Ethanol supply:** Since there will be a growth of demand for ethanol, existing ethanol plants need to scale up capacity (for plants with stable operation) or restart their operations (for plants that have discontinuous operations due to financial loss). Hence, it is necessary to provide loans with preferential interest rates for existing ethanol plants for capacity expansion or reoperation.

- **Biogasoline supply:** Key traders of gasoline need to invest and expand the capacity of the blending system. To encourage key traders to expand the blending system, incentives such as an exemption from import tax on machines and equipment used to blend biogasoline should be provided. Toward this end, the Ministry of Natural Resources and Environment (MONRE) must promulgate a list of imported machinery, equipment, vehicles, tools, and supplies used for environmental protection in accordance with Decree No. 134/2016/NĐ-CP "Guidelines for the Law on Export and Import Tax."

- **State management:** The Biofuel Roadmap No. 53 must be amended since E10 will be nationally commercialized.

Under the government's planned policies, CNG buses are predicted to reach between 9.89 percent and 12.07 percent of the total bus fleet by 2030. Based on this study, several policy instruments are necessary to drive CNG bus penetration in Vietnam.

Bus operation subsidy: The existing bus tariff is too low for bus companies, especially CNG bus companies, to recoup their costs. Hence, the government should provide direct subsidies to the bus companies based on the number of passengers carried on certain routes. For cities that already have a public transport subsidy policy, an increase in CNG bus subsidies for the first three years is needed to encourage them to enter the CNG bus market.

Fuel cost support: The government of Vietnam implemented subsidies for fossil fuels. The largest component of these subsidies is allocated to electricity, with a much smaller portion supporting transportation through consumer subsidies for gasoline and through producer subsidies in the form of reduced import tariffs for petroleum products. To promote CNG buses, the government should provide the primary CNG subsidies to transport operators to increase their affordability in the context of rising energy prices and to support the transport of citizens. On the other hand, the government can reduce tariffs for gas suppliers who sell CNG to transport operators.

Tax exemptions and incentives: Tax exemptions and incentives are necessary to attract international and domestic investors in developing a refueling station network. For example, investments in refueling infrastructure would benefit from a five-year income tax holiday, in addition to general foreign direct investment (FDI) tax exemptions and reductions on corporate income tax, import duty, and land rental charges.

Grants and concessional loans: Part of the perceived private investment shortfall, particularly for transport infrastructure projects, owes to the long time periods over which private sectors need to wait to see profit from their investment. Therefore, the government should support interest rates on commercial loans for investment in cleaner-technology buses and refueling infrastructure.

Guarantees: Loan guarantees have been made available to support the purchase of new buses for other investment by state-owned enterprises (SOEs) (or joint stock) bus companies.

Land incentives: Government support includes covering the costs of ground clearance and exemption from land-use levies. In general, investment in the compressed natural gas (CNG) bus infrastructure should be considered as an investment-incentive sector and exempted from land-use fees. These exemptions also apply to pilot public-private partnership (PPP) initiatives.

Infrastructure planning: The Ministry of Transport (MOT) or Departments of Transport (DOTs) should be responsible for forming clean-energy vehicle development planning, while the Ministry of Industry and Trade (MOIT) should coordinate with the MOT to establish the development plan of the refueling infrastructure network.

Investment and resource information: Based on the plans of clean-energy vehicles and refueling stations, the city government provides the basic information about services in the public transport, including a list of investment project opportunities to inform potential investors.

Appendix

APPENDIX A: **List of Data and Data Sources**

Data Source	Characteristics	Transport Mode	Activity Data	Fleet Composition	Traffic Situation
Trip survey (household surveys)	Data obtained through specific projects and specific cities	- Passenger car - Motorcycle - Taxi - Urban bus - Intercity bus	Per person: - PKT or - number of trips and distances	No	No
Vehicle activity survey	Data obtained through specific projects and specific cities	- Passenger car - Motorcycle - Taxi - Bus - Intercity bus - Truck	Per vehicle: - VKT or - number of trips and distances	No	No
Vehicle registration statistics	Data obtained from transport authorities	- Passenger car - Taxi - Bus - Intercity bus - Truck	Vehicle stock by technical characteristics	Yes, but only for stock, not for VKT	No
Traffic counting survey	Data obtained through specific projects and specific cities	- Passenger car - Motorcycle - Taxi - Bus - Intercity bus - Truck	Traffic volumes in the analyzed road section	No stand-alone data source, but for calibrating traffic model and estimating VKT development	No
Speed survey	Data obtained through specific projects and specific cities	- Passenger car - Motorcycle - Urban bus	Motor vehicle speed in the analyzed road section	No stand-alone data source, but for calibrating traffic model and estimating VKT development	Yes
Main inspection data (journey control device)	Data obtained from transport authorities	- Urban bus - Intercity bus - Truck	Per vehicle: - VKT	No	No

Data Source	Characteristics	Transport Mode	Activity Data	Fleet Composition	Traffic Situation
Public transport companies	Data obtained from transport companies or public transport authorities	- Urban bus	For the whole public transport network or for different routes: - Final fuel consumption - VKT - Ridership - Vehicle capacity - Load factors	- Bus per size and by fuel	No
Public transport network plan	Data obtained from public transport authorities or city transport plan	- Urban bus - UMRT	Length of each line	No	No
Intercity bus companies	Data obtained from transport companies	- Intercity bus	For the different routes: - Final fuel consumption - VKT - Vehicle capacity - Load factors	No	No
Intercity bus network plan	Data obtained from public transport authorities or national transport plan	- Intercity bus	Length of each line	No	No
Travel demand model (depending on year of calibration)	Data obtained through specific projects and specific cities.	- Passenger car - Motorcycles - Taxi - Urban Bus - Truck	Per road section: - Road length - Traffic volumes - VKT	No	Yes

Source: Study team.

APPENDIX B: **List of Transport Operators Using CNG Buses**

Hanoi

No.	Name of Company	Statistic Date	# of CNG Buses
1	Công ty TNHH DL DV Xây Dựng Bảo Yến	06/2021	129

Source: Study team.

Ho Chi Minh City

No.	Name of Company	Statistic Date	# of CNG Buses
1	Công ty cổ phần xe khách Sài Gòn	06/2021	123
2	Công ty TNHH MTV xe khách Sài Gòn	06/2021	6
3	HTX 19/05	06/2021	149
4	HTX 28	06/2021	27
5	HTX Quyết Thắng	06/2021	84
6	HTX Việt Thắng	06/2021	63
7	HTX Vận tải thành phố	06/2021	36
8	Khác	06/2021	8
	Total	06/2021	496

Source: Study team.

Binh Duong

No.	Name of Company	Statistic Date	# of CNG Buses
1	Tổng CTy ĐT & PT CN BECAMEX Bình Dương	06/2021	34
2	CN CTY TNHH Phúc Gia Khang	06/2021	33
3	Công ty CP Phương Trinh	06/2021	12
	Total		79

Source: Study team.

APPENDIX C: **Assumptions in the BAU Scenario**

1. Forecast of the number of cars and motorcycles

Cars and motorcycles are divided into two main categories: owned by households and not owned by households (vehicles used by companies, government agencies, businesses, etc.)

- The projection of private car ownership is based on the relationship between the number of household-owned vehicles and the expenditure of households. Household vehicle ownership in Vietnam is based on the the *Vietnam Household Living Standards Survey 2014* (GSO 2014). Gompertz and logistic functions will be used to analyze the relationship between a given number of vehicles (cars and motorcycles) and monthly household expenditure.

- The number of cars and motorcycles not owned by households in 2015, 2016, and 2017 is understood as the difference between the number of vehicles managed by the Vietnam Register and the survey data of GSO (2014). During the period from 2018 to 2050, assuming this number of vehicles is equal to the average data of the years 2014 to 2017.

2. Mortality vehicles

Over time, there will be a proportion of vehicles that cannot be used because of a number of reasons, including being too old, damaged in accidents, etc. These are known as mortality vehicles. The calculation of the number of mortality vehicles is based on the Winfrey S3 model as:

Survival = Yo*{1-[(i-b)^2/a^2]}^m

Where:

- Yo = survival when entering parc (100%)
- i = years of use
- a, b, and m adjusted so that new vehicle sales matches change in population. a and m are parameters ranging from, respectively, 7–10 and 0.7–40, which determine the peakedness (kurtosis) and the skewness of each curve. b is a parameter that basically determines the warranty period of the vehicle in which no retirement is usually expected.

3. Forecast of the number of passenger vehicles

The growth rate of passenger vehicle population follows the relationship between PKT/capita and GDP/capita. The relationship is represented by the following formula:

$$\text{PKT/capita} = e^{\left[m*\ln\left(\frac{GDP}{capita}\right)+c\right]}$$

Parameters m and c are determined from an analysis of 31 European countries (Eurostat data accessed March 1, 2013). Parameters represent best fit over the range of GDP/capita from US$1,500 per capita to US$7,000 per capita (Vietnam in our analysis goes from US$1,900 in 2014 to US$5,600 in 2030).

Annual projection for PKT is illustrated below:

TABLE C.1. **Annual Projection for PKT**

Timeline	Growth Rate for PKT
2015–22	5.3%
2023–33	5.2%
2034 onward	5.1%

Source: Study team.

- The number of LCV passengers from 2014 to 2016 was updated by VR report
- The number of buses included 9,264 buses at the national level (TDSI 2016)
- The number of coaches was reported from 2014 to 2016 by VR

4. Forecast of the number of freight vehicles

The growth rate of freight vehicles is based on the elasticity of GDP growth.

Elasticity

The relationship between the percentage growth in total freight transport and GDP growth was defined as the percentage change in freight traffic (freight ton-km transported) related to each 1 percent change in the country's GDP.

Arc elasticity was calculated using the formula:

$$\eta = \frac{\log F2 - \log F1}{\log G2 - \log G1}$$

where:

- η: arc elasticity
- F1: freight ton-km transported by all inland transport in year 1 (million metric ton-kilometers)
- F2: freight ton-km transported by all inland transport in year 2 (million metric ton-kilometers)
- G1: the country's GDP in constant 2010 US$ in year 1
- G2: the country's GDP in constant 2010 US$ in year 2

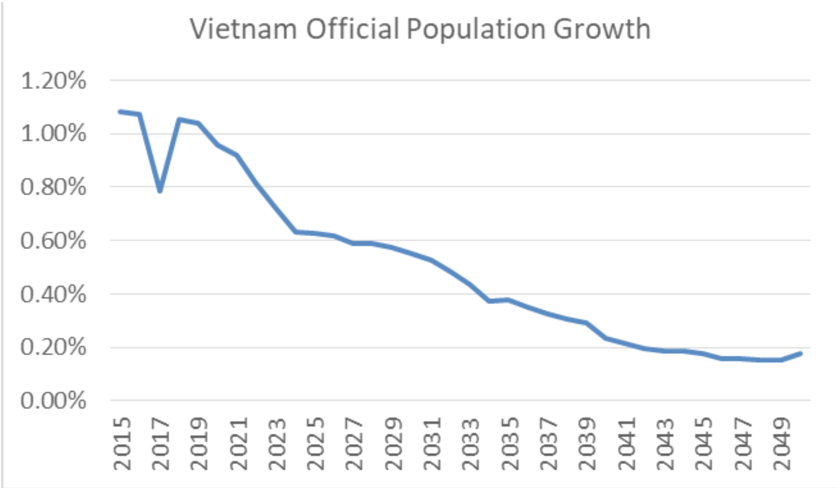
As can be seen, there is a weak decoupling of inland freight traffic to GDP per capita over the range of US$10,000 to US$35,000 per capita in OECD countries over the time frame of 1970 to 2016.

If this relationship were to hold true at lower GDP per capita values, it could be used to guide the expected increase in freight in Vietnam due to the expected change in population and GDP in the modeling to be used for the NDC update.

Currently, the EFFECT model used assumes a relationship of 1:1 for Vietnam between inland freight traffic growth and GDP growth over the 2014–55 timeframe.

The official DOE population and GDP growth rates used in the modeling are shown in Figure C.1 and Figure C.2.

FIGURE C.1. **Vietnam's Official Population Growth (2015 to 2050)**



Source: Vietnam Population Projection 2014–2050, General Statistics Office and United Nations Population Fund.

FIGURE C.2. **Vietnam's Official GDP Growth (2015 to 2050)**

Sources: General Statistics Office and Decision 428/QD-TTg on "The Approval of Revisions to the National Power Development Plan From 2011 to 2020 with Visions Extended to 2030."

Using these, together with the linear best fit shown in Table C.2, the elasticities that this would generate against GDP per capita for Vietnam are as follows. The elasticity to GDP is also shown in the table below.

TABLE C.2. **Elasticity to GDP per Capita and GDP**

Year	Elasticity to GDP per Capita	Elasticity to GDP
2014	1.0929	
2020	1.0890	1.0260
2030	1.0770	0.9498
2040	1.0536	0.8953
2050	1.0073	0.8411

Source: Study team.

It is recommended to keep the current approach of using a relationship between inland freight traffic growth and GDP growth of 1:1 for Vietnam over the 2014–50 timeframe.

Using the above relationship is tenuous and would make negligible difference to the scenarios being modeled.

The growth rate of FTKT will be similar to GDP growth.

The growth rate of freight vehicles will be the same as GDP growth.

- The number of LCV_goods was updated from 2014 to 2016 according to data of the Vietnam Register.
- The number of trucks will depend on the total FTKT on road needed to be carried per year.

REFERENCE

GSO (General Statistics Office of Vietnam). 2014. *Vietnam Household Living Standards Survey 2014*. Hanoi, Vietnam: General Statistics Office of Vietnam.

TDSI (Transport and Development Stategy Institute). 2016. "Proposal on Public Transport Quality Service Improvement."