SECTION A: KEY PRINCIPLES

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1 Introduction

1.1 Concept Framework

This Manual aims to synthesise in clear manner the key elements of current knowledge and experience to facilitate the application of best practice in improving Myanmar rural transport infrastructure in an affordable, sustainable and manageable way.

This chapter presents the background and aims of the Manual and outlines its structure. The Manual is introduced as providing practical guidance on the rational, appropriate and affordable designing of low volume rural roads in Myanmar that are compatible Rural Development Policy and the differing regional physical environments. There is an emphasis on the sustainable use of local resources and appropriate standards in an overall "Fit for Purpose" framework.

Poverty reduction has become the overarching goal for development that is shared by most international development agencies and their partners and member countries of the United Nations have agreed to work together to achieve the 'Sustainable Development Goals' (SDGs). It is an established maxim that effective transportation plays a crucial role in rural socio-economic development and in reducing poverty. Analysis has highlighted evidence that safe, effective rural transport will contribute substantially to more than half of the currently adopted SDGs (Engineers against Poverty 2016, Hine 2014 and Howe 1998).

SDG 1 to alleviate poverty;
SDG 2 to achieve zero hunger and ensure food security;
SDG 3 to ensure health and wellbeing;
SDG 4 to provide access to education;
SDG 5 to empower women in rural areas;
SDG 6 to facilitate access to clean water and sanitation;
SDG 8 to promote inclusive growth and economic opportunities;
SDG 9 and SDG 11 to contribute to sustainable infrastructure and communities for all;
SDG 13 to increase climate resilience and adaptation in rural areas.

In addition to indirect linkages to SDGs and associated targets, there is a direct linkage to rural access in SDG indicator 9.1.1 (Proportion of the rural population who live within 2 km of an all-season road) developed by the Inter-agency Expert Group on Sustainable Development Goals (ReCAP, 2018). The continued development of rural road networks in an affordable and sustainable way is increasingly important in order to provide cost-effective transport infrastructure, with the SDG aim to 'leave no one behind' (SuM4All 2017, 2019).

The Government of Myanmar considers improved rural roads to be a key to developing rural areas and addressing rural poverty and inequalities in the country in line with the SDGs. Although there is no dedicated SDG target on rural transport, there are numerous linkages between rural access and the SDGs (Cook et al, 2017).

Hence, the long-term development objective of the Government of Myanmar (GoM) is to provide all-season access to all villages in Myanmar. In support of this long-term development objective, the National Strategy for Rural Roads and Access targets the next 15 years (up to 2030), during which the Government of Myanmar aims to provide all-season road access to at least 80% of the villages in each state/region in Myanmar (GoM, 2017).

1.2 Manual Aims and Target Audience

This Low Volume Rural Roads Design Manual provides guidance on the rational, appropriate and affordable design and construction for low volume rural roads. In doing so it aims at making cost effective and sustainable use of local resources. The concept of local resources encompasses human resources, local government, and community institutions, local entrepreneurs, local technology and local materials.

The Manual reflects advances in low volume road technology gained in the region and elsewhere allied to accumulated local knowledge within DRRD and MoC (MC, 2015; Gourley et al, 2003; SEACAP, 2009; AfCAP, 2012; ReCAP 2016, 2018).

The application of appropriate design approaches for low volume roads in Myanmar aims to optimise whole service life construction and maintenance costs and meet requirements to:

- Improve the economic and social well-being of rural communities and their connectivity and access to social and other services;
- Develop the rural road network in a cost-effective and sustainable way;
- Lower road user costs and promote socio-economic development, poverty reduction, trade growth and wealth creation in rural areas;
- Protect and manage non-renewable natural resources and reduce import dependency.

This Manual is intended for use by roads practitioners responsible for the design of low traffic earth, gravel or paved roads throughout Myanmar. The main volume is appropriate for roads which, over their design life, are required to carry an average of up to about 300 equivalent ADT, and less than about 1.0 million equivalent standard axles (Mesa). An Annex to the main volume deals with an extension to 750 ADT and provides a link to guidance on higher volume rural roads. The Manual complements and links to the latest versions of other existing Myanmar reference documents relevant to LVRRs.

The Manual has been drafted to be fully adaptable for use by different stakeholders, at national, state, township and local level administered by authorities, enterprises or communities.

The document can cater for interventions that deal with individual critical areas on a road link (spot improvements) through to providing total rural road link designs.

1.3 Structure and Layout of Manual

The Manual is considered a Living Document that should be updated periodically as fresh information comes to light and new lessons are learnt from practical experience and ongoing research. Consequently, the hard copy has been produced in a format whereby individual chapters or annexes may be updated or replaced. The up-to date electronic version is held on, and can be downloaded from the DRRD/MoC website.

The current structure of the Manual comprises 3 principal Sections, 14 Chapters and a number of Annexes, as is summarised in Table 1.1.

Table 1.1 Manual Structure and Content

Reference	Content
Section A	**Key Principles**
Chapter 1	Provides an overview of the Manual, its application, context, and use.
Chapter 2	Outlines relevant Myanmar Policy, the legal framework and overall strategic standards.
Chapter 3	Introduces the philosophy of low volume road design and presents the overall framework within which the design and construction process takes place.
Chapter 4	Introduces the concept of the Road Environment and describes the particular challenges of the Myanmar Road Environments and provides advice on addressing the various issues of climate, hydrology, materials, traffic, terrain, construction & maintenance regimes, road safety and the green environment.
Section B	**Design**
Chapter 5	Provides guidance on road alignment and road asset investigation procedures and recovery of design data from initial planning through to final design and construction amendment. Procedures include desk studies, site investigation and materials testing.
Chapter 6	Provides guidance on Geometric Design, including influential factors, and aspects of traffic characteristics, cross section, alignment, and safety.
Chapter 7	Provides guidance on Surfacing and Pavement Design and the range of design options using the materials available, from Engineered Natural Surfaces (ENS), through gravel to various paving techniques, and issues of internal pavement drainage.
Chapter 8	Addresses Construction Materials issues for each component of the road works and the desirability to optimise the use of locally available resources and the challenges of scarce resources in some areas of Myanmar.
Chapter 9	Provides guidance on Cross Drainage and structures, including hydrology, components of road works drainage, erosion control and challenging terrain.
Chapter 10	Addresses the design and sustainability of road-side slopes including road earthworks and protection issues together with geotechnical bio-engineering solutions.
Section C	Implementation
Chapter 11	Provides summary guidance on the application of the issues addressed in Section B by means of clear flow-charts and check lists.
Chapter 12	Addresses issues in the construction LVRRs, including planning, quality control and as-built reporting.
Chapter 13	Addresses the vital issue of Asset Management and maintenance and outlines the basic aims and principles.
Chapter 14	Outlines the use of Technical Audits and summarises their objectives and structure and application.

Annexes	
I. Traffic Assessment	Provides detail on the procedures for undertaking and analysing traffic surveys including worked examples.
II. Laboratory Testing (Soils and Rocks)	Provides reference detail and comment on the most common soil and rock test methods undertaken in support of LVRR design and construction.
III. Marginal Materials	Provides a review of the character and uses of natural construction materials that may be marginally acceptable in terms of specification.
IV. Ground investigation Techniques	Provides additional detail on the selection and use of Ground Investigation techniques applicable to LVRR design and construction.
V. DCP Options	Summarises the use of the Dynamic Cone Penetrometer (DCP) as a design and construction supervision tool.
VI. Spot Improvement	Gives guidance on the application of the Spot Improvement concept in LVRR design and construction.
VII. Higher Volume Traffic	Gives guidance on the design implications of increasing the upper limits of LVRR traffic from 300 ADT (1 Mesa) to 750 ADT (3 Mesa).

References

AfCAP, 2012. South Sudan Low Volume Roads Design Manual. DFID for Ministry of Roads and Bridges, S Sudan

Cook J R, Petts R, Visser C & You A, 2017. The Contribution of Rural Transport to Achieve the Sustainable Development Goals. Research Community for Access Partnership (ReCAP) Paper, ref. KMN2089A, for UKAID-DFID

Engineers Against Poverty, 2016. Maximising the Social Development Outcomes of Roads and Transport Projects. Guidance Note for the Chartered Institution of Highways and Transportation

Gourley C, Greening A, Jones D & Petts R., 2002. Paving the way for rural development and poverty reduction

Government of the Union of Myanmar (GoM), 2017. National Strategy for Rural Roads and Access

Hine J, 2014. Good Policies and Practices on Rural Transport in Africa; Planning Infrastructure & Services. SSATP, The World Bank Group, Washington.

Howe, J. 1996. Transport for the Poor or Poor Transport? A general review of rural transport policy with emphasis on low-income areas, IHE Working Paper IP-2, Delft: International Institute for Infrastructural, Hydraulic and Environmental Engineering

MoC, 2015. Road Design Criteria. Department of Roads, Ministry of Construction, Government of the Union of Myanmar, Naypyidaw

ReCAP, 2016. Tanzania Low Volume Roads Manual. DFID for President's Office, Regional Administration and Local Government (PO-RALG)

ReCAP, 2018. Status Review of the Updated Rural Access Index (RAI), Final Report, GEN2033C by Vincent, S., Civil Design Solutions (2018). London. ReCAP for DFID

SEACAP, 2009. Rural Road Standards and Specifications Classification, Geometric Standards and Pavement Options. Final Project Report. DFID for Royal Government of Cambodia

Sustainable Mobility for All (SuM4All). 2017. Global Mobility Report 2017: Tracking Sector Performance. World Bank, Washington DC. http://www.sum4all.org

Sustainable Mobility for All (SuM4All). 2019. Global Roadmap of Action: Universal Rural Access Companion Paper. World Bank, Washington DC. http://www.sum4all.org

2 Policy, Standards and Specifications

2.1 Introduction

The development of an effective and sustainable rural road network requires it be designed, constructed and managed within a framework of appropriate classification, standards and technical specification driven by a clear strategic policy. Without such a framework the challenges of cost-effectively managing the network and its assets become insurmountable.

This chapter sets the scene for the later Design Section by summarising the key principles applying to standards and specification and sets them within the current Myanmar policy and strategy, whilst referring back to recommendations made in the UKAID-funded document "Review of Low Volume Rural Road Standards and Specifications in Myanmar" (Dingen and Cook, 2018).

2.2 Classification, Standards and Specifications

Aims

An appropriate rural road design approach requires a framework comprising of important technical elements:

- Classification;
- Standards;
- Specifications;
- Design Manual.

Fundamentally, Standards fit the needs of a working Classification; there are then sets LVRR Technical Specifications that define how the roads and associated structures and earthworks must be built to comply with the Standards. Finally, there is usually an overarching document or manual, such as this document defining the application of the standards and specifications, parts of which will be included in any required contract information or Terms of Reference.

The aim of the Classification-Standards-Specification framework is to ensure that roads within the Myanmar rural road network adhere to the following key strategic principles:

- Consistent with the Myanmar Rural Development Strategy;
- Compatible with the various road environments in Myanmar;
- Fit for Purpose;
- Sustainable.

Classification

A Classification system is necessary for effective management and delegation of responsibilities and also provides important outcomes that relate to the class assigned to each road, including:

- Establishment of road design criteria;
- Development of road management systems;
- Planning of road construction and maintenance;
- Guidance to the general public.

Classification allows for the division of road networks into manageable groups so that broadly similar good-practice design options can be adopted that are neither under-designed or over conservative and costly. It is accepted that there is a strong correlation between traffic level/growth rates and the administrative function of a road and therefore an administrative classification is commonly seen as a suitable option. However, although traffic levels often increase in line with the administrative classification hierarchy, this is

not always true and, furthermore, the traffic levels are likely to differ considerably between different areas and different regions of Myanmar. The traffic on a village-to-village road in Ayeyarwady might be considerably different from that than on a similar road in Magwe or Taunggyi. The design approach should reflect this. Thus, although an administrative classification may be necessary to enable ownership, responsibilities, resources and management to be assigned should also cater for differing road tasks or purpose.

Standards

A network road 'standard' defines a minimum level of service and performance that should be achieved at all times. This translates to a set of agreed norms, uniformly applied in the design. Amongst other things this ensures consistency across the country. Thus, for roads this means that road-users know exactly what to expect and road managers know what they must achieve and maintain (SEACAP, 2009).

In terms of safety, drivers should not be 'caught out' by unexpected changes in quality and geometry and will not unexpectedly find that a road is too narrow, or that they must alter their speed drastically to avoid losing control of their vehicle. Thus, standards are a guarantee of a particular quality level and although they are not synonymous with specifications they could, and often are, incorporated into specifications and contract documents.

Experience has shown that simply adopting international standards from developed countries is not an appropriate way forward for rural road network development, as these normally do not take the specific road environment and financial constraints into account. There are important differences between high volume National Road standards and LVRR standards; the two are not generally interchangeable (Cook et al 2013).

Technical Specifications

Technical specifications define and provide guidance on the design and construction criteria for rural roads to meet their required level of service. They define actions, procedures or materials that should be used to design, construct and maintain LVRR networks and their constituent roads. As with LVRR standards the use of locally appropriate documents is imperative. For example, the use of locally available, but frequently nonstandard, pavement construction materials plays a significant role within this concept. Technical specifications cover a wide range of issues.

Table 2.1 Typical LVRR Technical Specification Groups

Specifications	Description
Design and Construction	These provide detailed requirements by which elements of a LVRR should be constructed and include key issues such as; Pavement, Earthworks, Drainage, Small Structures.
Construction Materials	These define the acceptable limits (properties such as strength, durability etc.) for the selection and use of construction materials, both natural and man-made.
Quality Assurance and Quality Control.	Defines the methods to be used in terms of supervising the quality of LVRR elements and the use of specified equipment and testing procedures.
Maintenance Activities	Defines the procedures to be used in undertaking the different types of LVRR maintenance; routine (mechanical and non-mechanical); periodic and emergency.
Laboratory Testing	Defines the laboratory testing procedures to be used. In contrast to other standards and specification these are usually based on international procedures, such as AASHTO or ASTM.

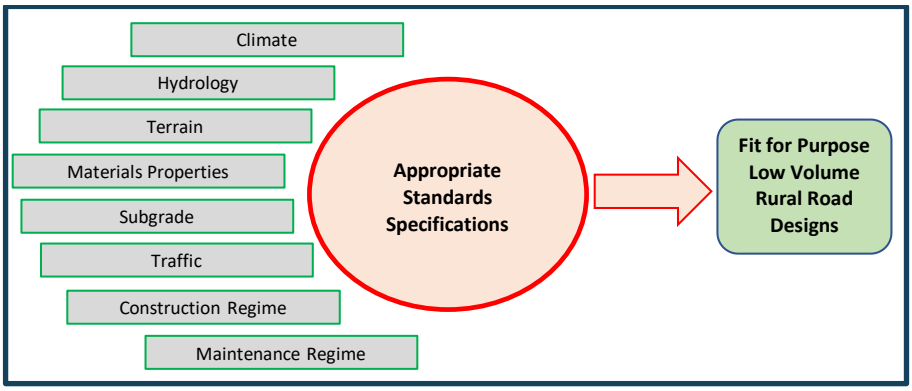
2.3 Myanmar National Policy and Strategy for Rural Roads

Background

The National Strategy for Rural Roads and Access (NSRAA) is the basis for the improvement of the Myanmar rural road network. It was jointly prepared by the Ministry of Agriculture, Livestock and Irrigation (MOALI) and the Ministry of Border Affairs (MOBA) with technical support from the Asian Development Bank (ADB) in 2017. It serves to guide investments in the rural road sector and provides a framework within which appropriate rural road classification and standards should be applied to the development of a Core Rural Road Network (CRRN).

A point to be emphasised is the need for flexibility in the working standards for LVRR within the CRRN to be applied to a range of physical environments in Myanmar. The concept of "fitness for purpose" is proposed as the key foundation for the design philosophy driving the drafting and application of this Manual, Figure 2.1.

Figure 2.1 The Links to Fit for Purpose LVRRs



Policy Aims

The NSRRA states that nearly 15% of registered villages in Myanmar are not connected by road. Of the villages that are connected by road, more than 40% are linked by dry-season rural roads that quickly become impassable during the rainy season. Altogether, half of the existing registered villages are physically isolated during part or all of the year due to a lack of all-season rural road access, affecting over 14 million rural people (GoM, 2017).

Roads in the context of Myanmar sustainable development

The NSRRA defines a core aim of the Government of Myanmar as providing registered villages with all-season road access. It also provides general guidance on the classification and prioritisation of the Core Rural Road Network (CRRN) which is defined as the "minimum rural road network in a township required to connect all villages to each other and to the higher-level road network". The following connectivity rules apply:

1. Villages that are not directly connected by higher-level roads will be connected by a single rural road that will be classified as a CRRN road.
2. Where a village is connected only by one rural road, that road will be selected as part of the CRRN.
3. Where a village is connected by more than one rural road, the best road will be selected to form part of the CRRN, taking account of the length, surface type, and condition and traffic volumes in the different existing rural roads.
4. Where a village is not connected by any road, if possible, a tentative alignment will be identified, which will be selected as part of the CRRN for new construction.

The CRRN will consist of the existing single road access for each connected village, as well as the tentative alignments for new construction linking unconnected villages. Locations with important economic or cultural importance may also be connected by the CRRN. In 2017 the total CRRN road length was assessed as being 111,170 km of which only 30% were classed as being of "all season" standard (GoM, 2017).

2.4 Existing LVRR Classification, Standards and Specifications in Myanmar

General

This Manual should be used within the overarching framework of current documents and associated definitions. The current (2019) documentation is contained within the in the 'Book of Standards', which is an internal compilation by MoC of national road construction specifications, which originate from 1983 and stipulate work methods and material specifications for construction, earthwork and pavement.

Although specific rural road standards are under review by MoC, coordinated by the Central Committee, there are currently no specific LVRR standards and specifications for Myanmar, although the previous ReCAP report makes appropriate recommendations. The Design section of this Manual therefore, whilst working within the current general framework includes variations based on Myanmar LVRR environment.

Current LVRR Classification

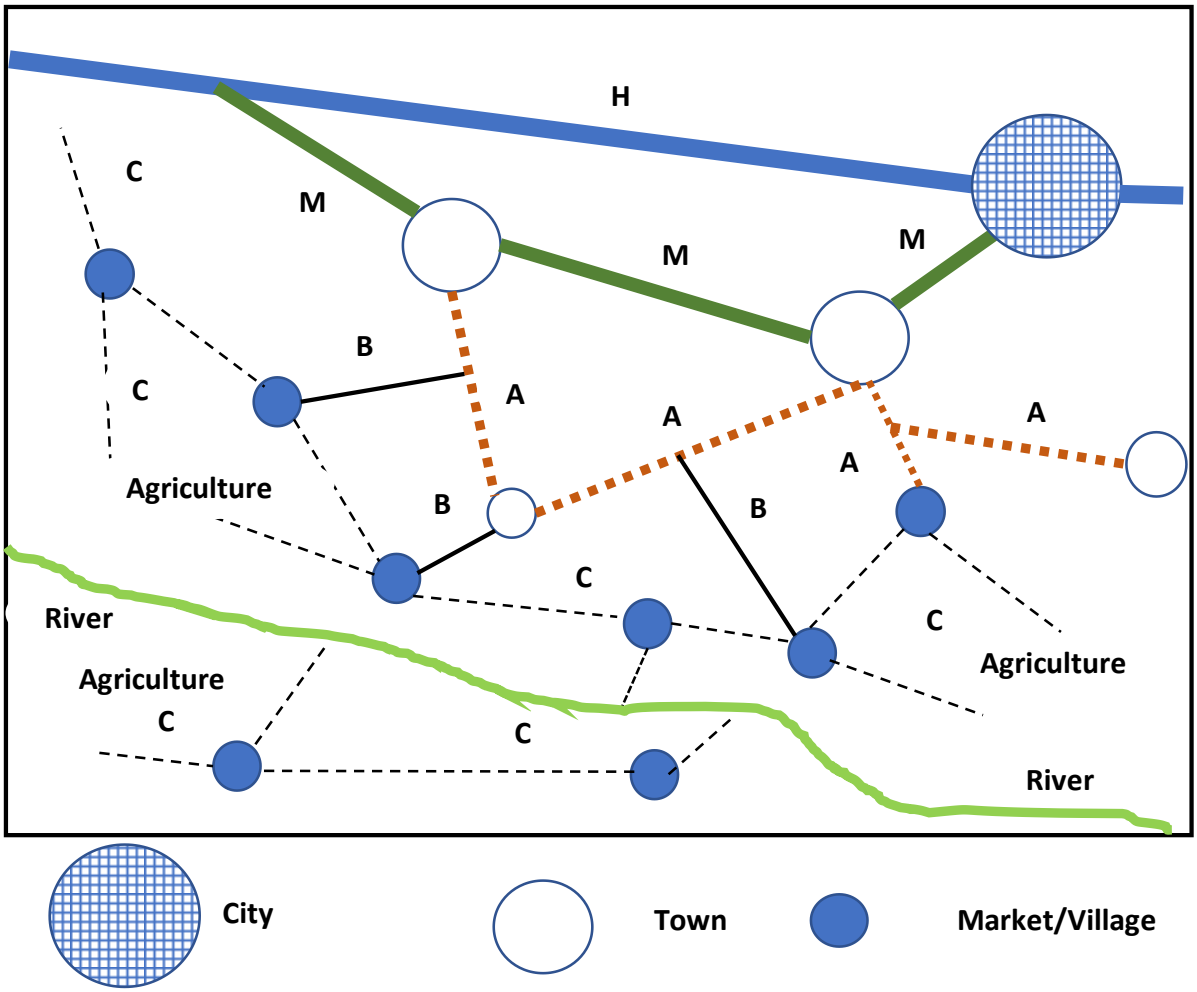
In parallel with the work undertaken to establish the NSRAA the Central Committee for the Development of Regional Roads and Bridges has broadly classified rural roads into three administrative classes. The first two administrative classes (A and B) may include core network roads, while the third class (C) comprises lower level rural roads. The classes are defined as below and as illustrated in Figure 2.2, and are linked to road widths and some pavement general options as outlined in Table 2.2.

1. **Class A** rural roads include all core rural roads that connect village tracts or that connect rural populations of over 1,000 people with the higher-level road network. This may involve a road connecting a single large village but may also involve a road (section) connecting multiple villages with a combined population of more than 1,000 people. Due to the larger populations served by class A roads and the importance of providing good connectivity for village development committees and for services and facilities provided in the village tracts, higher standards and specifications will be applied to class A rural roads. Class A rural roads generally connect directly to the higher-level roads or to towns and cities

2. **Class B** rural roads include all other core rural roads connecting villages and serving populations of less than 1,000 people. These class B rural roads serve smaller villages or fewer villages, and will have lower standards and specifications than Class A roads, but will be constructed and upgraded to an all-season standard. Class B rural roads will generally connect to class A rural roads, although it is possible that they connect smaller villages directly to higher-level roads or towns.

3. **Class C** rural roads include all other rural roads that are not defined as part of the core rural road network and that do not serve as the main connection to a village. Although these class C rural roads provide additional access to agricultural fields and link habitations that are located away from the main village, they do not contribute to the main objective of this strategy. As such, they do not have priority for upgrading to an all-season standard.

Figure 2.2 Illustration of Broad 3-Fold NSRAA Classification



H: Highway M: Main Road A,B,C: Rural Roads as per NSRAAA classification.

Source: Based on Government of Myanmar, 2017

Table 2.2 Summary of Key Aspects of the Current Myanmar LVRR Divisions

Class	Traffic (esa)[1]	Carriageway Width (m)	Shoulder Width (m)	Recommended Pavement Option
A	300,000	5.5	3.0	Bitumen seal over crushed stone/gravel base & sub-base; Un-reinforced concrete slab over crushed stone/gravel sub-base.
B	<300,000	3.6	1.2	Bitumen seal over crushed stone/gravel base & sub-base; Un-reinforced concrete slab over crushed stone/gravel sub-base. Gravel wearing course over crushed stone/gravel sub-base.
C	Not defined	3.6	0.5-1.0	Gravel wearing course over crushed stone/gravel sub-base; Earthen road.

[1] esa : Equivalent Standard Axles over design life of the road

Standards and Specifications

The 'Book of Standards' includes a series of standard drawings for 3 classes of rural roads, 4 types of bridges and a range of box and pipe culverts as well as a vented causeway. The drawings and the road construction technical specifications are tabulated and indicated on the standard drawings. The National Rural Road Standards and Specifications which follows from the NSRRA will in due course further define minimum specifications of the all-season standard.

Flexibility in Standards and Specifications

LVRR standards and designs need to support the function that the road is providing as well as recognising the important influences of the deterioration mechanisms linked to the local environment. The LVRR Classification, Standards and Specifications must be flexible and appropriate to the regions of Myanmar such that the roads and their assets are:

1. Task based – they suit the road function and its traffic (the people as well as the vehicles) which will pass along them.

2. Local resource-based and compatible with the road sector in Myanmar: the engineers and technicians who will design the roads, the contractors and labourers who will construct them, the villagers who maintain them and the construction materials that are available.

3. Facilitate the construction of roads with whole life asset costs that will not exhaust the provincial and district budgets or place excessive maintenance burdens on local communities.

2.5 Myanmar Environmental Policy, Regulations and Standards

Environmental Impact Assessment

Roads provide substantial economic benefits to local communities and national economies and provide access to health services, education and employment. But roads can also generate significant and long term adverse impacts to the environment and communities (TRL, 2005). Some of the recognized impacts of roads as enumerated by USAID's (2018) sectoral guidelines for rural roads are the following:

- Loss of ecosystem services;
- Soil erosion;
- Degradation of water quality;
- Adverse effects on quantities of water;
- Altered hydrology and flooding;
- Deforestation;
- Damage to valuable ecosystems;
- Habitat diversity;
- Damage to scenic quality and tourism;
- Adverse impacts on human health and safety;
- Changes to local culture and society.

Because of the road's potential environmental impacts, road projects are subjected to the environmental impact assessment (EIA) process. Globally, governments have adopted and are enforcing environmental impact assessments for development projects, including roads. Likewise, international funding institutions (IFIs) require road projects they support to comply with their respective environmental and social safeguards policy.

The Government of Myanmar specifically, has adopted its environmental policy in 1994. This National Environmental Policy is proclaimed by Notification No.26/94 dated 5 December 1994 and among its essential components is environmental management. Subsequently, the Government of Myanmar enacted

environmental laws, regulations and standards to implement the policy. The relevant environmental laws and regulations include the Environmental Impacts Assessment Procedures Law of 2015, cultural and heritage protection law, forestry law, wildlife protection and protected areas law.

The Environmental Conservation Law and the Environmental Impacts Assessment Procedures Law of 2015 stipulates that all projects and project expansions undertaken by any ministry, government department, organisation, corporation, board, development committee, local government or authority, company, cooperative, institution, enterprise, firm, partnership or individual which may cause impact on environmental quality are required to comply with the environmental regulations. Annex 1 of the EIA Procedures Law (2015) lists roads among the projects that should be screened and categorized according to severity of impacts.

The compliance commences with submission of a project proposal to the Environmental Conservation Department (ECD) for screening and categorization as per the provisions of the Environmental Impact Assessment Procedures Law (2015). Based on the outcome of the review of the project proposal, ECD issues a decision on the scope and TOR for the required environmental report, whether a comprehensive environmental impact assessment (EIA) or initial environmental examination (IEE, abbreviated impacts assessment). Environment and conservation laws that are relevant to development projects including roads are summarized in Table 2.3.

Table 2.3 Summary of Environmental Policy, Regulations and Laws of Myanmar

Ref	Document	Description
1	National Environmental Policy (passed 05 December 1994)	It proclaims the government's commitment to the principle of sustainable development. It also highlights the integration of environmental considerations into the development process to enhance the quality of life of all its citizens.
2	The Environmental Conservation Law (passed March 2012)	The provisions of this law encompass waste management and pollution control, the adoption of environmental quality standards, environmental permitting of projects or activities, management of urban environment and the protection of natural and cultural resources.
3	Environmental Conservation Rules (passed June 2014)	The environmental impact assessment implementation law of Myanmar, stipulating the requirement for projects and activities to secure environmental permit. It also stipulates the requirement for firms and individuals that conduct environmental impact assessment to register with the MOECAF (now MONREC).
4	Environmental Impact Assessment Procedures Law (passed December 2015)	Law enacted pursuant to the Environmental Conservation Law of 2012. It establishes the environmental impact assessment procedure from project screening, scoping, investigation, reporting, review, approval and monitoring; it enumerates the general content and coverage of IEE and EIA studies; provides the transitory conditions for projects in progress at the time of the enactment of the law; it enumerates the authority of MONREC in the review and approval; It also provides a categorization of projects / activities for the purpose of environmental permitting.
5	The Protection and Preservation of Cultural Heritage Regions Law (The State Peace and Development Council Law No. 9/98, passed September 1996)	This law governs the protection of the cultural resources of Myanmar which includes ancient monuments or ancient sites, structures, houses, walls, moat, stone inscriptions, carvings among others. Among its provisions are the prohibited acts and penalties.
6	Forestry Law (State Law and Order Restoration Council Law No. 8/92 passed 1992).	Repealed the 1902 Forest Act. Enforces among others the forestry and environmental conservation policies of the Government and developing the State's economy. Among its provisions relevant to RRRP are (i) all standing teak trees, regardless of location, are owned by the State (known as a Reserved Tree); (ii) permits are required for extracting or moving forest produce and establishing Wood-based industries; and (iii) any tree which cut within a township (such as the trees along the project road) cannot be removed from the township unless a permit is given by MOECAF (now MONREC).
7	National Environmental	This contains the environmental guidelines for emissions and effluents from various

Ref	Document	Description
	Quality (Emission) Guidelines (issued December 2015)	specific sources including roads and construction activities.
8	Health and Safety Legislation and Standards	The new Law on Safety and Health in Workplaces' drafted by the Ministry of Labour (MOL) requires the prevention of air and water pollution and to improve safety at worksites, including fire prevention, and the requirement for construction workers to use protective equipment, ensuring the safety of worksite operators and taking precautions for natural disasters.
9	The Conservation of Water Resources and Rivers Law of 2006	This law is aimed at (a) conservation and protection of the water resources and rivers system for beneficial utilization by the public; (b) safety of navigation in waterways i.e. rivers and creeks; (c) to contribute to the development of State economy through improving water resources and river system; (d) to protect environmental impact.

Environmental Standards

The Government of Myanmar has yet to declare its environmental standards; in the meantime, it issued National Environmental Quality Emission Guidelines (NEQG) in December 2015. The guidelines cover both water and atmosphere emissions related to a wide range of projects and industries including construction. These Guidelines have been primarily excerpted from the International Finance Corporation (IFC) Environmental Health and Safety (EHS) Guidelines, which provide technical guidance on good international industry pollution prevention practice for application in developing countries. Among the environmental guidelines adopted at the World Health Organisation (WHO) Ambient Air Quality Guidelines (IFC 2007), the noise guidelines, the quality of run-off from construction sites and effluent. Also, environmental quality guidelines for effluent from extraction of construction materials (borrow sites, quarry) has been issued as part of the National Environmental Quality (Emission) Guidelines (2015).

2.6 Complementary Intervention Measures

General

In simple terms, Complementary Interventions take advantage of the presence of a road project to build-in aspects that will enhance the social, environmental and safety situation of communities affected by the road. These are additional to the statutory social, environmental and safety obligations of the road authority (DRRD), designer and contractor. They may enhance, but do not replace existing, safeguards required either by Myanmar Government regulation or by Donor guidance documents (World Bank 2016, ADB 2013).

Complementary Interventions can generally be grouped into three categories:

1. Management Interventions – simple actions that enhance the road project itself and are well within the normal skills required of a LVRR designer or contractor. These aim to improve the wider impacts of the project itself and build on or extend the normal socio-environmental and safety obligations of the project
2. Opportunity Interventions – actions that are beyond the scope of traditional LVRR projects but are within the technical and management skills of the designer or contractor.
3. Enhancement Interventions – actions that utilise the framework of the project but extend beyond the normal skills and experience required for the design and construction of a LVRR. These actions would normally be implemented by additional parties with the necessary relevant skills.

Complementary Interventions are demand driven, reflecting the needs expressed by local communities themselves, and are agreed through interaction and dialogue local groups. Within an outline framework, agreed at the pre-feasibility or feasibility stage, the task of the design engineer is to materialise these desires and agreements into the LVRR design and its contract documentation.

Complimentary Intervention Examples

2.6.1.1 Road and Site Safety

Category 1 Management Interventions

- Provide additional markings/warnings at dangerous areas;
- Extend provision of access to specific services and facilities for pedestrians, NMTs and IMTs (e.g. motorbikes, tiller-tractors);
- Provide road safety education to employees;
- Provide access to first aid training for community representatives and to facilities in emergency;
- Rigorously enforce speed limits of construction equipment and plant.

Category 2 Opportunity Interventions

- Distribution of reflective strips for pedestrian, IMT and NMT road users;
- Provide boards warning community of construction and road hazards;
- Provide refresher/first aid training for local health officials.

Category 3 Enhancement Interventions

- Road safety awareness: Schools/community road safety education campaigns;
- Provide Road Safety equipment, teaching aids or additional equipment.

2.6.1.2 Road Corridor Environment

Category 1 Management Interventions

- Provide temporary and permanent accesses to homes, tracks and paths;
- Provide water and hand sprinkler systems to local communities to control dust on road sections near their properties as needed during construction;
- Reinstatement of diversion roads – consider transferring ownership for use by IMTs, NMTs (particularly in busy/dangerous areas);
- Reinstatement of temporary work areas – e.g. provide designs for utilisation of borrow pits to dams or fish ponds;
- Provide opportunity for community to claim spoiled materials including wood from grubbing, topsoil or oversize stone;
- Provide additional soil protection and road/structure erosion protection in vulnerable areas.

Category 2 Opportunity Interventions

- Plant agriculturally productive trees and plants along roadside and in borrow areas;
- Establish landfill/waste management sites, utilising borrow and quarry areas where appropriate, or areas designated by local authorities;
- Repair to areas suffering previous erosion or siltation damage;
- Improve access to the road through access tracks, trail bridges, footpaths;
- Improve access from the road to local community facilities;
- Provide road maintenance or supervision training to local groups and administrations;
- Rehabilitate and repair community/village assets: roads, market areas, meeting areas, sanitation/water supply facilities and drainage systems.

Category 3 Enhancement Interventions

- Establish nurseries for supply of trees and shrubs for bio-engineering;
- Provide protective tubing for saplings, covers for seedlings and water supply;
- Extend productive planting to other areas identified by local communities;
- Supply fingerlings for borrow areas upgraded to fish ponds;

- Build community/village assets – school rooms, health or veterinary posts, storage facilities training/meeting rooms;
- Utilise road drainage system to provide water-harvesting facilities.

2.6.1.3 Road Transport Services (RTS)

Category 1 Management Interventions

- Ensure adequate physical access for pedestrians and that normal RTS is maintained during construction;
- Provide adequate bus-bays and shelters.

Category 2 Opportunity Interventions

- Provide local vehicle maintenance training to local groups;
- Provide technical skills training to local transport service operators
- Make available mechanical workshops for local IMT/RTS repairs.

Category 3 Enhancement Interventions

- Provide gender balanced awareness training on options for RTS;
- Provide seed financing for establishment of rotating funds for supply and maintenance of local RTS.

2.6.1.4 Support Services

Category 1 Management Interventions

- Provide vehicles and temporary emergency first aid services for local communities whose access to mainline services is hindered by construction works;
- Supply local health centres with drugs relating to communicable disease control.

Category 2 Opportunity Interventions

- Provide HIV/AIDS testing and counselling services along the road corridor for construction workers and local communities;
- Distribution of fist aid supplies to health posts;
- Assist with the repair or rehabilitation or maintenance of health and education centres.

Category 3 Enhancement Interventions

- Provide classroom furniture and promote use of ICT in schools;
- Provide mosquito nets and mattresses to health centres and nurseries;
- Provide support to community awareness initiatives on health, gender balance, ethnic integration, safety, livelihoods and income generation;
- Provide water supply/construct sanitation facilities for roadside communities.

2.6.1.5 Community Development

- Category 1 Management Interventions
- Maximise employment opportunities for local groups, including women and ethnic minorities– provide crèche and other support facilities.

Category 2 Opportunity Interventions

- Provide advisory services to local administration with regards to construction rehabilitation or maintenance of community infrastructure;

- Provide ground water recharge schemes, water harvesting or small micro-irrigation schemes;
- Provide materials equipment and training to support establishment and development of local SMEs;
- Supply materials, skilled advice and equipment for community projects.

Category 3 Enhancement Interventions

- Provide office furniture, accommodation and sanitation facilities for community facilities;
- Provide gender balance life skills training (e.g. literacy, numeracy, basic accounting, kitchen gardening, sanitation and hygiene,) to local community groups and SMEs.
- Specific ways of construction need to be considered to take into account the future effects in low lying areas of Myanmar to increase the safety of population during extreme climatic events through:
  - Increased availability of appropriate climate disaster shelters,
  - Improved access to shelters,
  - Improved facilities of existing climate disaster shelters;
  - Awareness-building and motivating stakeholders/beneficiaries on climate change issues, keeping facilities in order, and evacuation scenarios.

Encouraging participation of marginalised groups

There are population groups that are, for whatever reason, disadvantaged or excluded from participation in employment. Often these groups can benefit most from temporary employment in road works projects.

Typically excluded groups include:

- Women in general and especially mothers with young children;
- Physically or mentally disadvantaged;
- Ethnic or religious minorities;
- Pastoral communities;
- HIV/AIDS affected or infected people.

It should be recognised that the labour required at road sites usually require physically hard work and construction sites can be relatively dangerous places. It may not, therefore, be appropriate to require contractors to exclusively employ the above groups, however, there may be opportunities, for example, at the work camp, that allow for engagement and employment of marginalised groups.

It is necessary for the design engineer to develop an understanding of any barriers to participation in employment by women and minority groups, and find ways to help them access employment; without causing conflict or concern amongst the wider community.

Planning

Complementary Interventions need to be treated as an integral part of the planning process, in much the same way as environmental and social safeguards. Provision for them should be included in the long and medium term budgets to prevent them being removed due to inadequate budgeting or funding allocation.

The identification and development of Complementary Interventions should take into account current Myanmar national, regional and sector policies; legal instruments; international conventions and treaties; guidelines and procedures relating to public consultation/participation; local development planning and implementation.

Complementary Interventions need to be considered early in the project cycle and be an integral part of project planning, from project identification to feasibility study. It is important that the client (DRRD) and key stakeholders work together to develop an outline plan for inclusion of Complementary Interventions in the road project/programme to a sufficient level of detail for their further development during the detailed design. The outline plan and budget for Complementary Interventions, and an assessment of the potential impacts, should be included in the economic analysis of road projects as they may raise the economic rate of return of the road investment, despite any initial additional costs.

In developing a detailed design for Complementary Interventions, it is essential that the design engineer works through DRRD and with the appropriate departments and structures. For detailed design, a high level of consultation with affected communities will also be needed. The design engineer should work through DRRD or MoC to ensure that the correct local procedures are adopted and that the appropriate formalities are followed. Decisions, prioritisation methods and approvals for planned initiatives would be introduced by DRRD and achieved through their existing local level structures.

The design consultant should refer to participatory approach manuals from other line ministries in developing their own detailed methodology for identification and selection of complementary activities for each low volume road project. The design engineer should also become familiar with existing local and regional development plans (e.g. the NSRAA), potential sources of complementary financing or resources that may be allocated to the complementary activities, willingness of local communities to make other contributions, work by local NGOs and other organisations.

Low Volume Road projects can cover relatively long distances, can cross a number of local administrative boundaries, and affect a number of different communities. Identification of Complementary Interventions may therefore not be a simple task of consulting one community to identify their development needs and priorities, but may require consultation and negotiation with different communities; each possibly with their own internal structures and cultures, needs and priorities.

The key stakeholders will be expected to have a deeper understanding of the beneficiary communities than the Client and should be able to provide guidance on the most locally acceptable means for engaging with local communities and appropriate participatory decision-making methods.

Implementation

The key to successful implementation of Complementary Interventions will be ensuring that clearly defined requirements and adequate provisions are included in project documents and at all programme stages.

During project planning, DRRD will determine the approximate budget and scope of the project, including the budget and scope for Complementary Interventions. This then needs to be reflected in the Request for Proposals (RFP) and, in particular, the Terms of Reference, for consulting services for the detailed design. The RFP should specifically include appropriate inputs of key personnel with the requisite skills to meet the requirements of the client with regards Complementary Interventions.

DRRD may directly assist with the development of the Complementary Intervention package with regards to Category III interventions, as it could be far more efficient and appropriate for them to undertake the identification and preliminary selection using the existing appropriate government structures and plans.

The development of Category I and II intervention packages are relatively straight forward and should be easily within the skill area of a competent multi-disciplinary design team. However, the RFP still needs to be well developed and throughout.

The feasibility study should develop the preliminary options and budget/cost estimates for the Complementary Interventions. The detailed design will require preparation of the finalised list of Complementary Interventions, detailed designs and engineers cost estimates.

In general, the Complementary Intervention aspects of the contract should be managed monitored and enforced using the normal provisions of the contract documents.

Complementary Interventions should be included in the contractors detailed work plan and the payment schedule. Progress and performance should be reported through the monthly site meetings and progress reports. It may be appropriate to prepare specific reports for local communities and their leaders on the progress of Complementary Interventions in their area. The frequency of such reports would depend on the nature and scale of Complementary Interventions being implemented in that area, which should be determined during the detailed design stage and uses provisions made in the reporting sections of the works and supervision contracts.

While it is the Contractor's responsibility to manage and implement the Complementary Interventions according to the Contract, it is the Engineer's responsibility to ensure Complementary Interventions are monitored regularly and that technical and performance standards are met.

Monitoring and enforcement should be closely linked to the contractor's payments. It is essential that measurement and payment for Complementary Interventions and any incentives or penalties are clearly defined in the works contract.

References

ADB, 2013. Social Protection Operational Plan 2014–2020. Asian Development Bank, Manila, https://www.adb.org/sites/default/files/institutional-document/42704/files/social-protection-operational-plan.pdf.

AfCAP, 2012. South Sudan Low Volume Roads Design Manual. DFID for Ministry of Roads and Bridges, S Sudan.

Cook J, Petts R C and J Rolt 2013. Low Volume Rural Road Surfacing and Pavements: A Guide to Good Practice. AFCAP Report GEN/099, Crown Agents, UK

Dingen, R & Cook J R. 2018. Review of Low Volume Rural Road Standards and Specifications in Myanmar. AsCAP Project Report for DRRD.

Government of the Union of Myanmar (GoM), 2017. National Strategy for Rural Roads and Access.

IFC, 2007. Environmental, Health and Safety Guidelines, World Bank Group. https://www.ifc.org/wps/wcm/connect/topics_ext_content/ifc_external_corporate_site/sustainability-at-ifc/policies-standards/ehs-guidelines

ReCAP, 2016. Tanzania Low Volume Roads Manual. DFID for President's Office, Regional Administration and Local Government (PO-RALG).

SEACAP, 2009. Rural Road Standards and Specifications Classification, Geometric Standards and Pavement Options. Final Project Report. DFID for Royal Government of Cambodia.

TRL, 2005. ORN5 A guide to road project appraisal.

USAID, 2018. Sector Environmental Guidelines; Rural Roads.

World Bank, 2016. Fact Sheet. The World Bank's New Environmental & Social Framework. World Bank, http://pubdocs.worldbank.org/en/748391470327541124/SafeguardsFactSheetenglishAug42016.pdf

3 The Approach to LVRR Design

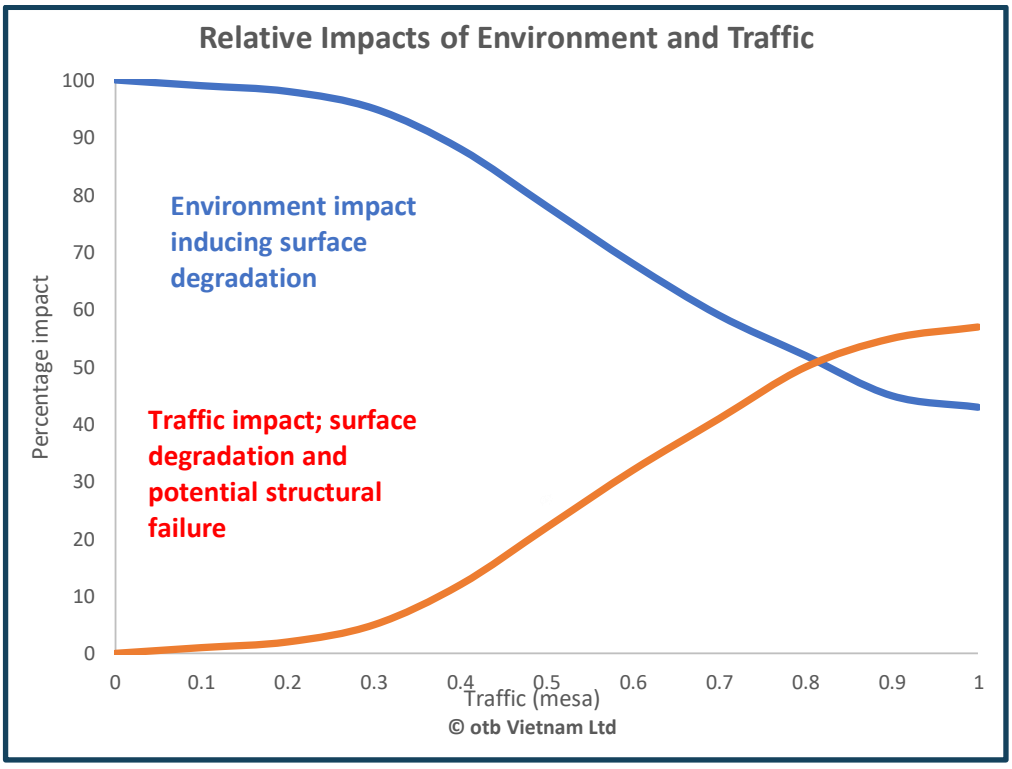
3.1 Introduction

During the past 20 years there have been significant advances in research and its application on various aspects of Low Volume Rural Roads (LVRRs specifically with the aim of reducing costs and increasing the effectiveness of the provision of such roads for rural and peri-urban communities. Much of this work has been highly successful, resulting in innovative approaches that can provide beneficial and cost-effective solutions for these roads, particularly, for example, in the use of local materials and alternative road surfacing (TRL, 2000, Intech-TRL, 2009).

This chapter outlines a general approach to LVRR design that underlies the more detailed guidance given in the Design Section of this Manual. Emphasis will be put on fitness for purpose; road environment compatibility; sustainability and the use of local resources.

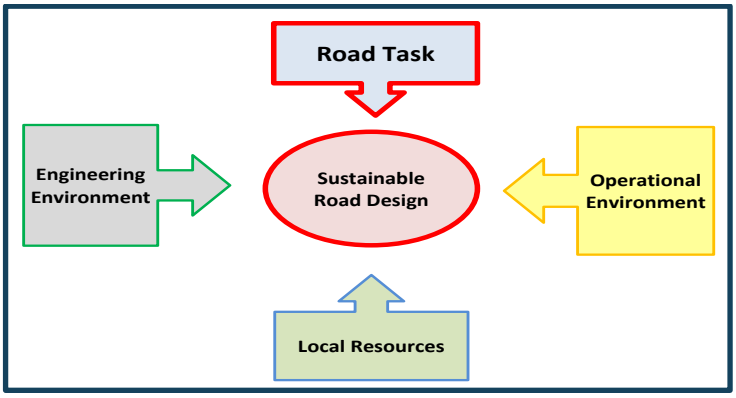
As noted in Chapter 1 an upper limit of 200 to 300 equivalent motorised vehicles per day is taken as being appropriate in most situations. This is equivalent to up to about 0.8 to 1 million equivalent standard axles (Mesa) during the design life of the road pavement. Figure 3.1 places this upper limit in the context of the relative importance of surface degradation and structural failure as dominant design issues.

Figure 3.1 Design Traffic and Environment Impacts on LVRRs



Although the approach to the design of LVRRs follows the general principles of good-practice road design (Cook et al 2013), there are a number of important issues to be appreciated by the designer in order to provide designs appropriate to the variable Myanmar social, economic, physical and climatic environments. One fundamental issue is that the design process should be in line within the principle that the roads should be designed to be compatible with the local governing factors as outlined in Figure 3.2.

Figure 3.2 Factors Governing Sustainable LVRR Design



Source: Intech-TRL (2006)

3.2 A different approach

Key Issues

There are a number of key, sometimes conflicting, issues that relate specifically to LVRR design and construction:

1. On low volume, low axle load road environments the principle degradation issue may be physical erosion and climate induced degradation. In the case of very low volume roads (< 10,000 esa) conventional designs based on subgrade and traffic may be irrelevant.
2. On many LVRRS in Myanmar there may be an emphasis on motorcycle or tiller tractor traffic (IMT), Non-Motorised Traffic (NMT) or pedestrian traffic, which should influence the geometric cross-sections, for example, in terms of wider shoulders.
3. The variety of traffic types throughout Myanmar requires an analysis of appropriate PCU weighting factors for geometric road design.
4. There are frequently significant constraints in terms of budgets for LVRR programmes, requiring an emphasis on prioritisation and a focus on Spot Improvement options.
5. There is an emphasis on using local construction materials, although these are scarce or are of marginal or poor quality in some Myanmar regions.
6. Because of the lower design standards for LVRRs, they are particularly vulnerable to current and future climate impacts and consequently informed decisions on climate resilience prioritisation have to be made.
7. LVRRs that connect with mains roads (i.e. Class A rural roads) are at risk from high axle loads and these needs to be assessed at an early stage in the design process.

The Road Environment

It is recognised that, to a greater extent than higher volume roads, the design-life performance of LVRRs is influenced by the impacts of what is termed the 'Road Environment' and, in particular, by the Engineering and Operational Factors that are summarised in Table 3.1 and Table 3.2 and indicated diagrammatically in Figure 3.3.

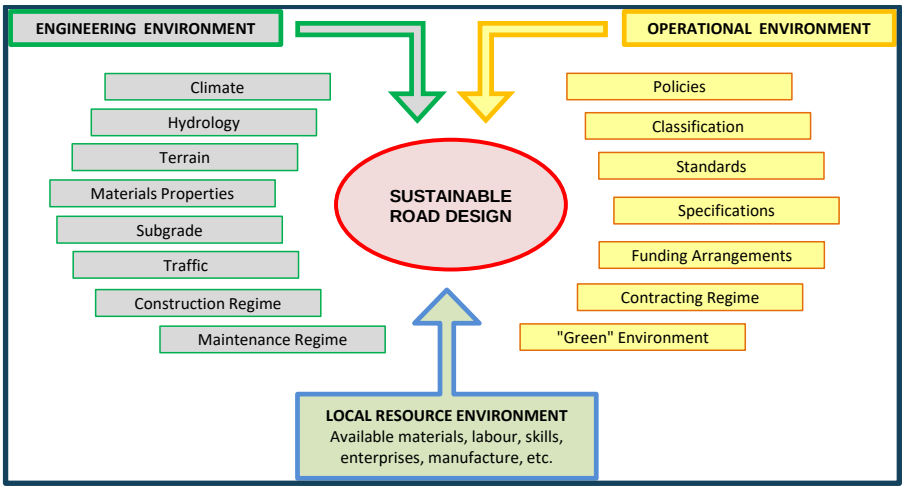
Table 3.1 Road Engineering Environment Impact Factors

Impact Factor	Description
Climate	Current and future climate will influence the supply and movement of water and impacts upon the road in terms of direct erosion, flooding and the influences of the groundwater regime. Unpaved surface performance is particularly influenced by quantity and intensity of rainfall, and runoff arrangements. Climatic i can have a significant influence on the selection of pavement options. Major climate "shock" events are high risk to LVRRs.
Surface and sub-surface hydrology	Current and future hydrology is the major impact factor on the siting and design of cross-drainage structures. The interaction of water or its movement within and adjacent to the road structure has an over-arching impact on the performance of pavements, earthworks and drainage structures. Changes in near-surface moisture condition are the trigger for significant sub-grade and earthwork volume changes in pavements underlain by "expansive" clay materials.
Terrain	The terrain reflects the geological and geomorphological history. It has an obvious influence on the horizontal and vertical alignment (geometric design and grade) of the road and earthwork requirements. It is also a controlling factor on the geometry of river catchments.
Materials Properties	The nature, engineering character and location of construction materials are key aspects of the road environment assessment. For LVRRs, where the use of local materials is a priority, the key issue should be; 'what design options are compatible with the available materials?' rather than seeking to find material to meet standard specifications, as is the case with higher level roads. Specifications need to be appropriate to the local environment.
Subgrade	The subgrade is essentially the foundation layer for the pavement and the assessment of its in-service condition and is critical to detailed pavement design.
Traffic	Although recent research indicates that the relative influence of traffic on LVRRs is often less than that from other road environment parameters, great consideration still needs to be given to the influence of traffic and, in particular, the risk of axle overloading on light road pavements. The traffic mix should influence the basic road geometry, including the use of wide shoulders for pedestrian or bicycle use.
Construction Regime	The construction regime governs whether or not the road design is applied in an appropriate manner. Key elements include: – Appropriate contractual framework; – Experience of contractors or construction groups; – Skills and training of labour force and supervisors; – Availability, use and condition of appropriate construction plant; – Selection and placement of materials; – Quality assurance; and compliance with specification; – Technical supervision.
Maintenance Regime	All roads, however designed and constructed, require regular maintenance to ensure that their basic task is delivered throughout the design life. Achieving this depends on the maintenance strategies adopted, the timeliness of the interventions, and the local capacity and available funding to carry out the necessary works. When selecting a road design option it is essential to assess the actual maintenance regime that will be in place during its design life so that designs may be appropriately adjusted where necessary, and/or the maintenance regime may be enhanced if necessary.

Table 3.2 Road Enabling Environment Factors

Impact Factor	Description
Policies	National or local policies will provide guidelines, requirements and priorities for the decision-making processes. There will also be legal requirements with which to comply.
Classification	Road classifications based on task or function provide road planners and designers with a practical guidance framework to initially select and cost appropriate road options. Having a clear rural road classification linked to relevant standards facilitates design and construction within acceptable performance criteria.
Standards (Geometry and Safety)	Geometric standards will influence not only the comfort and safety of road users but also the impact of water management on and across the road and the effects of earthworks on the local terrain and environment. LVRRs are likely to be required to accommodate a wide range of users from pedestrians through to trucks.
Technical Specifications	Technical specifications define and provide guidance on the design and construction criteria for roads to meet their required level of service within the classification-standards framework. Specifications appropriate to the local engineering environment are an essential element of an effective enabling environment.
Funding Arrangements	Available funding has an over-arching influence on the scale and nature of the roads and their pavements that are feasible. Funding availability for on-going road management and maintenance throughout the road design life is also a key issue.
Contracting regime	The nature of the general contracting regime can influence a road project through the following issues: – Local legislation and contract documentation; – Governance and level of bureaucracy; – State-owned or private contractors; – National or international contractors; – Arrangements for facilitating local SMEs, – Local resources and low-capital approaches
The “Green” Environment	Road construction and on-going road use and maintenance have an impact on the natural environment, including flora, fauna, hydrology, slope stability, health and safety. These impacts have to be assessed and adverse effects mitigated as much as possible by appropriate design and construction procedures.

Figure 3.3 Road Environment and Impact Factors, Cook et al (2013)

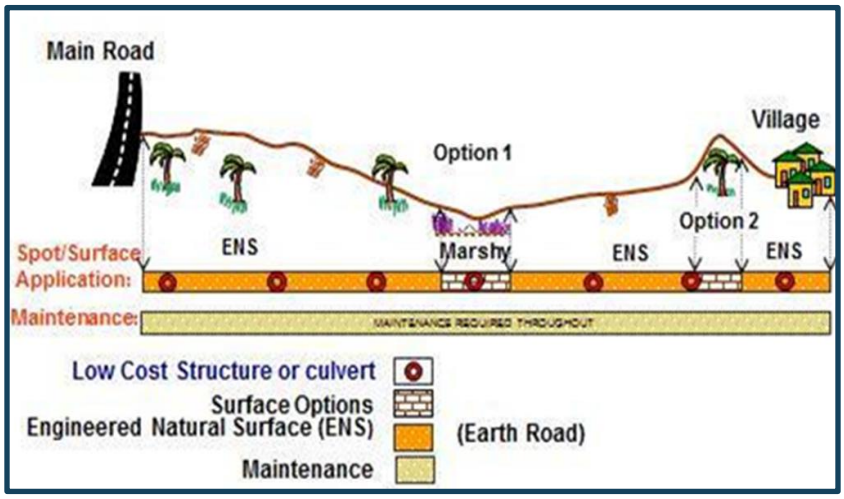


LVRR Strategic Design Options

For more cost-effectively improving LVRR networks the concept of an appropriate, or Environmentally Optimised Design (EOD), approach provides a pragmatic way forward in constrained resource situations. EOD covers a spectrum of solutions for improving or creating low volume rural access; from dealing with individual critical areas on a road link (Spot Improvements) to providing a total link design (Whole Length Improvement). EOD provides a framework for the common situation where the aspirations of local communities have to be balanced with very limited budgets.

Under an EOD approach, the road is designed to suit the variety of tasks and environmental factors such as rainfall, available materials, construction capacity, gradient, flood risk, maintenance regime and so on. Some of these factors vary from road to road and from location to location along a road. Therefore a road design may vary along its length with, for example, a sealed surface up a hill or gravel along a level section, Figure 3.4.

Figure 3.4 Illustration of the EOD or Spot Improvement Option



Source: Roughton International (2006)

3.3 Design Approaches within the LVRR Life-Cycle Roadmap

The LVRR Life-Cycle Roadmap

The road project Life Cycle (Figure 3.5) can act as a route map and guide to the acquisition of relevant knowledge and the appropriate levels of data required for making knowledge-based design decisions. This information and its related decision requirement are summarised in Figure 3.6, which is used as the driver for investigation planning in Chapter 5 of the Design Section of this Manual.

Figure 3.5 Project Life Cycle

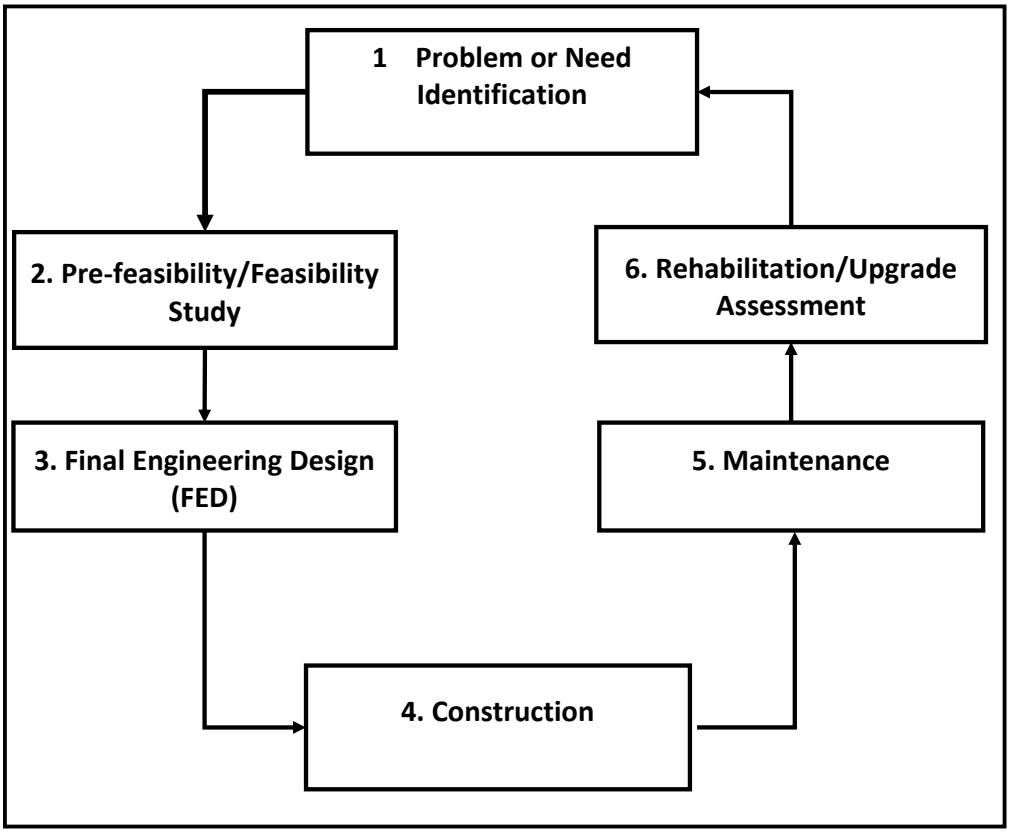
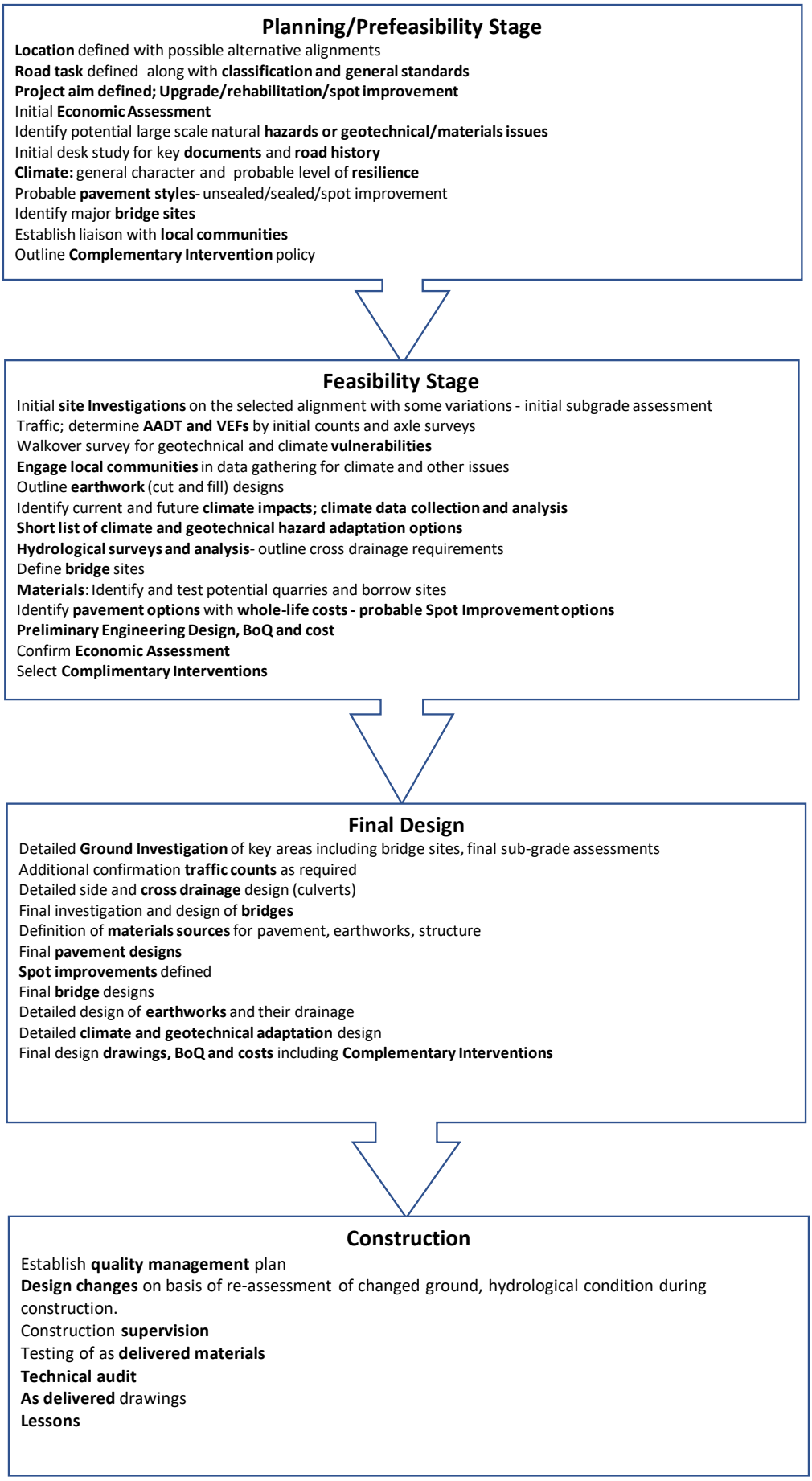


Figure 3.6 Activities in Project Cycle Phases leading to Construction



Whole-Life Costs

In assessing the design options for a LVRR project it is recommended that consideration must be given to Whole-Life Costs (WLCs), rather than simply immediate constructions costs. For example, the option of unsealed roads may appear attractive in immediate cost terms however in WLC terms the options for sealing can, in some environments be cheaper in WLC terms (SEACAP, 2006).

Whole Life Costing is a process of assessing all costs associated with a road over its intended or design lifetime. The aim is to reduce the sum of these values to obtain the minimum overall expenditure on the road asset whilst achieving an acceptable level of service from the asset. Usually an assessment of the residual value of the asset at the end of the assessment period is included. There are two basic approaches to the assessment of whole life costs for rural roads that can each reflect discrete objectives and may result in different conclusions depending on the local circumstances. These can be characterised as:

- Whole Life Costs for the Road Asset (Whole Life Asset Costs)
- Whole Life Transport Costs

Whole Life Asset Cost (WLAC) assessment aims to define the costs of Construction and Maintenance of a particular road and pavement over a selected assessment period. The principal cost components are the initial investment or construction cost and the future costs of maintaining (or rehabilitating) the road over the assessment period selected (for example, 12 years from construction).

Since the purpose of the road is to cost-effectively transport the local road users, Whole Life Transport Costs assessment will, in addition, include a component for the savings in Vehicle Operating Costs for the road users under the various investment and maintenance strategies. This component can be substantial on higher traffic rural roads. Other socio-economic factors may also be included in the assessment. The aim is to minimise the overall transport costs (infrastructure and means of transport) over the assessment or design lifetime and will usually incorporate cost savings or other benefits to the road users and community.

Any assessment will only be as good as the data and knowledge used in the relationships incorporated in the evaluation. For many rural road evaluations, the confidence in the cost data is generally good for construction components but often less so for maintenance costs and road performance. The knowledge and confidence may be poor for local Vehicle Operating Costs (VOCs) under the range of possible road conditions and for the range of transport vehicle types, hence, practitioners tend to use Whole Life Asset Costs (WLAC), initially at least.

Climate Resilience

The Myanmar National Strategy for Rural Roads and Access requires that use will be made of climate resilient designs that take account of the differences in climate vulnerability (flood risk, erosion risk, rainfall, drought, etc.) in the various parts of the country. Appropriate designs should be applied that find a balance between the risks of climate impacts and related repair and maintenance costs compared to initial climate resilience construction costs. This will result in different areas applying different designs in line with the expected climate impacts in those areas, reducing total lifecycle costs and increasing the sustainability of improved access.

Climate resilient aspects in designs will primarily be evident in the level of the carriageway, the construction materials used (to withstand flooding and erosion), the types and dimensions of drainage structures (to deal with increased rain volumes and intensities and related peak runoff flows), and the slope and embankment protection measures (to avoid collapse due to flooding, erosion or landslides)[2].

Future climate predictions for Myanmar projections indicate that by 2100 the following are considered probable (UNHABITAT 2017):

[2] In the preparation of the new National Rural Road Standards and Specifications, suitable design standards for the different areas of the country are expected be identified and trialled.

- Mean annual temperature increase of 0.5°C (low emission scenario) to 5.5°C (high emission scenario), with highest projected increases in the centre and north.
- A weakened monsoon climate and decreased cloud coverage, leading to increased drought periods.
- An increase in rainfall variability - during the wettest months (May–October) rainfall ranges from a decrease of 45 mm/month to an increase of 200 mm/month.
- Increase in frequency and severity of extreme weather events, including cyclones/strong winds, flood/storm surge, intense rains.
- Sea level rise of 0.2–0.6 m or more.

These predictions have obvious implications in terms of threats (Table 3.3) to vulnerable sections of the rural road network that need to be addressed in specific design approaches (ADB, 2011). In terms of the project life-cycle, identification of the specific climate design threats needs to be undertaken early in the design process in order for budgetary and strategic adaptation decisions to be made.

Table 3.3 Climate change Impacts

Impact Factor	Description
Increase of temperature	Faster evaporation will cause the soil moisture to be reduced. Material expansion will cause fragility of concrete roads, bridges, culverts. May require change in selection of bitumen types for sealed roads
Increase of rainfall and intensity	Floods, erosion of embankments and road infrastructure. Erosion of embankments and increased risk of roadside slope failures (landslides).
Sea level rise	Area flooding of coastal and deltaic areas. The road assets also affected by saline intrusion.
High winds associated with typhoons	Potential damage to structures as well as secondary damage from trees and other debris. Impact by wind driven wave action on embankments, bridge abutments, road pavements.
Increase of the frequency of strong major storm events	Flood levels above design assumptions. Erosion and damage to earthworks, pavements and bridges. Reports suggest roads are partially damaged when surge height/ depth of inundation is less than 1m, and more fully damaged when the depth of inundation exceeds 1m

Sustainability

The concept of overall sustainability is a crucial issue in the context of road network development. In addition to ensuring that the design developed is technically appropriate and is within the financial envelope, the design engineer needs to bear in mind other factors that could influence the success of the LVR design approach, its implementation and its long term sustainability, Table 3.4.

Table 3.4 Key Sustainability Issues

Component	Requirement
1. Politically supported	The road programme is compatible with an identified national policy and is supported in all its aspects at central and local levels.
2. Environmentally sustainable	The road construction as well as its subsequent use and maintenance should not cause significant environmental damage and be compatible with current environment legislation.
3. Financially sound	There must be adequate funding in place for construction, management and long-term maintenance of the road and its assets over its proposed design life.
4.Technically appropriate	The road design is compatible with clearly identified national rural transport requirements and related socio-economic policies, and is in line with clearly identified socio-economic and transport needs.
5. Socially acceptable.	The project is capable of being embraced by and fostering existing social safeguards on issues such as: community acceptance and participation, gender equality, and protection of vulnerable groups.
6.Instititionaly possible	The road project is within the technical capacity of the available road designers and contractors with the necessary resources, knowledge and experience to carry it forward.
7. Economically viable	The benefits accruing from the programme in terms of social and economic developments must be greater than its initial and on-going costs.

It is useful at an early stage to rate each component as an aid to identifying and mitigating problems through the design process, for example:

1. Not sustainable.
2. Significant sustainability concerns.
3. Moderate sustainability concerns.
4. Minor concerns.
5. No sustainability concerns.

References

ADB, 2011. Guidelines for climate proofing investment in the transport sector: Road infrastructure projects. Asian Development Bank, Manila.

Cook J, Petts R C & Rolt J. 2013. Low Volume Rural Road Surfacing and Pavements: A Guide to Good Practice. AFCAP Report GEN/099, Crown Agents, UK.

Roughton International, 2008. Local resource solutions to problematic rural roads access in Lao PDR; SEACAP access roads in Route 3. Module 2 - Completion Report. SEACAP 17, DFID report for MPWT, Lao PDR.

Intech-TRL, 2006. Rural Road Surfacing Research, SEACAP 1 Final Report. DFID for MoT Vietnam.

UNHABITAT, 2017. Assessing Climate Risk in Myanmar; Summary for Policymakers and Planners SEACAP, 2006.

4 Myanmar Road Environments

4.1 Introduction

Myanmar has wide range of physical, climatic and development environments that need to be taken account of in the design, construction and management of the rural road network and the previous Chapter 3 has indicted the range and importance of the Road Environment impacts in this regard.

This chapter focuses on the key impact / factors with regard to individual regions. Key design issues are highlighted for each Myanmar region and sources of information and key data sources are listed for use by LVRR practitioners.

4.2 General Myanmar Physical Setting

Physical Units

Myanmar, a country of 676, 575 sq. km can be divided into 3 major physiographic units, the mountain ranges, the central lowlands and the coastal and deltaic plains. The distribution of these units in the country is outlined in Table 4.1.

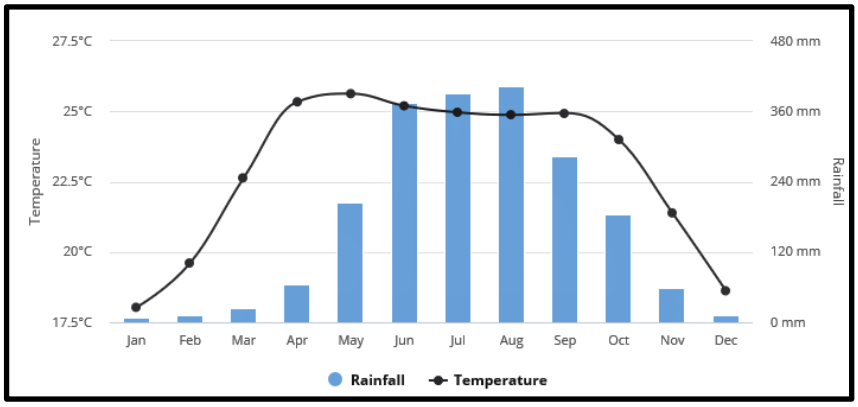
Table 4.1 Myanmar Physical Setting

Physiographic Units	The Physiographic Regions
Mountain Ranges	Northern range
	The western mountain range (Rakhine Yoma)
	The eastern mountain range (Shan Hills)
	The central mountain range (Pegu mountains)
Central Lowlands	Sagaing-Mandalay-Magway
Coastal and deltaic Plains	Rakhine, Thanintharyi and Ayeyarwady coastal and deltaic plains

Climate

In general terms, Myanmar experiences a tropical-monsoon climate with three dominant seasons, summer, rainy and winter season. As described by Htwe (2015) the summer season prevails from end of February to beginning of May with highest temperatures during March and April. From November to end February is the winter season with temperatures in hilly areas of over 1000m dropping to below 32F (0°C) with average temperature across the country of 10 to 18°C. The rainy season prevails from mid-May to October which coincides with the southwest monsoon which brings in majority of the precipitation of Myanmar, Figure 4.1.

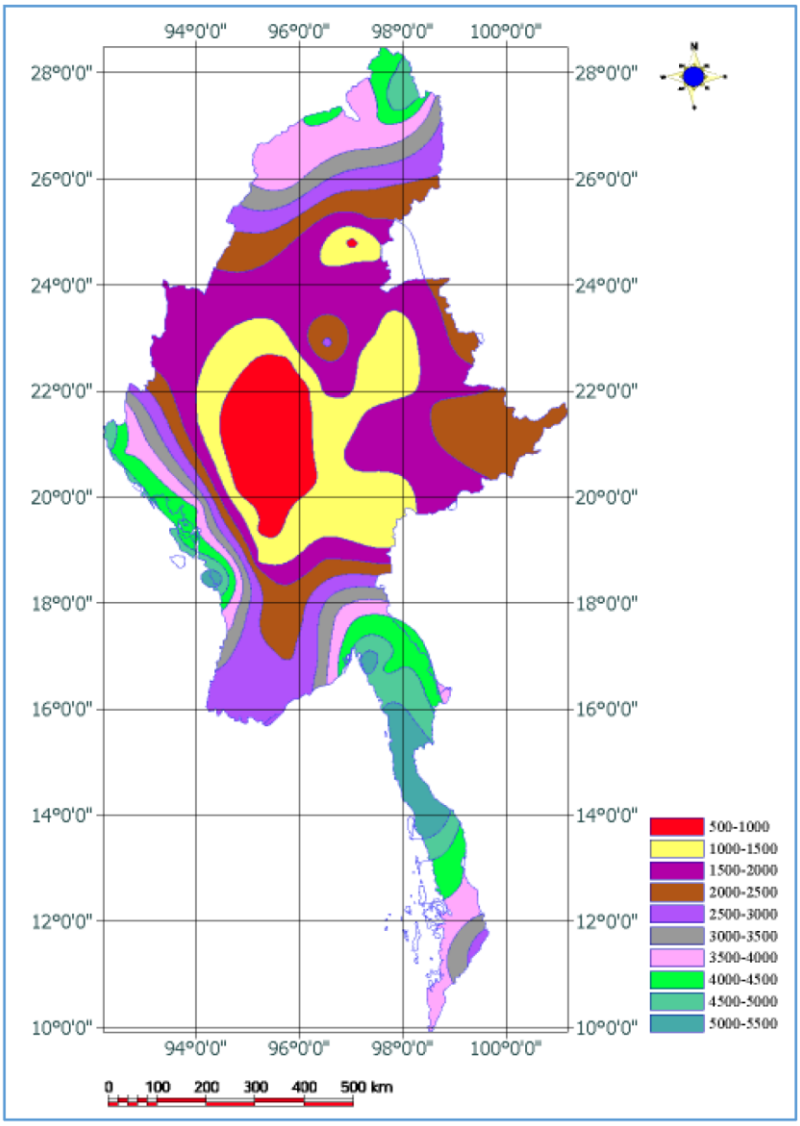
Figure 4.1 Average Monthly Temperature and Rainfall for Myanmar 1901-2016



The Southwest Monsoon (rainy season) has four (4) stages, the pre monsoon (Mid-April onset), early monsoon (June), mid or peak monsoon (July, August), late monsoon (September withdrawal) and post monsoon (October, November). The Southwest monsoon sets in initially in lower Myanmar about the third week of May, extending gradually northwards and is usually established over the whole country by about the first week of June. The highest annual precipitation is observed in the Rakhine Coastal Region, followed by the Ayeyarwady Delta.

The Central Dry Zone, because of the geographic setting, has a distinct climate of dry season from Mid-November to mid-May and a wet season for the rest of the year. Just like the rest of the Ayeyarwady basin, most of the annual rainfall occurs during the monsoon season that prevails from May to October. According to Drury (2017), the rainfall is generally bimodal with July being drier than the other monsoonal months. The north-south alignment of ranges and valleys creates a pattern of alternate zones of heavy and light precipitation during both the northeast and southwest monsoons. Most of the precipitation, however, comes from the southwest monsoon. The west coast is subject to tropical cyclones. Currently the coastal regions and the western and south-eastern ranges receive more than 5,000 mm of precipitation annually, while the delta regions receive about 2,500 mm. The central region is not only positioned away from the sea but also on the drier rain shadow side of the Rakhine Mountains. Precipitation gradually decreases northward until in the so-called Dry Zone it amounts to only 500 to 1,000 mm per year. The Shan Plateau, because of its elevation, usually receives between 1,900 and 2,000 mm annually**.** Figure 4.3 presents summaries of the climate for four representative climatic regions within Myanmar.

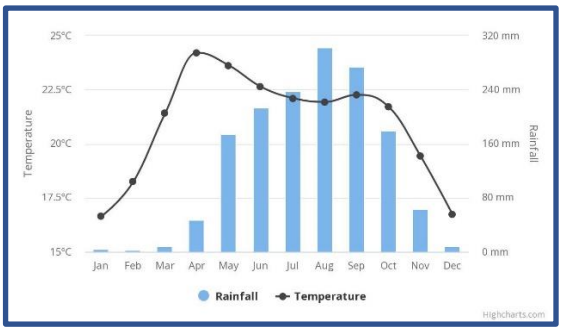
Figure 4.2 Myanmar Rainfall Variations



Source: DMH

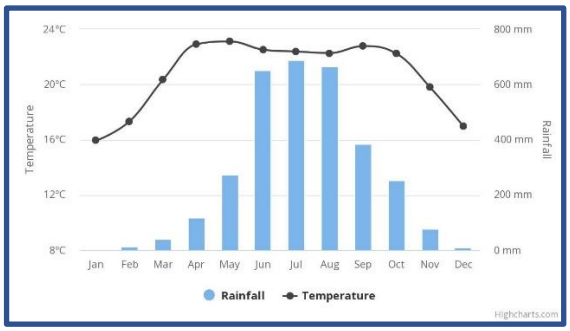
Figure 4.3 2016 Regional Climate Variations

Shan State (Tauynggi)



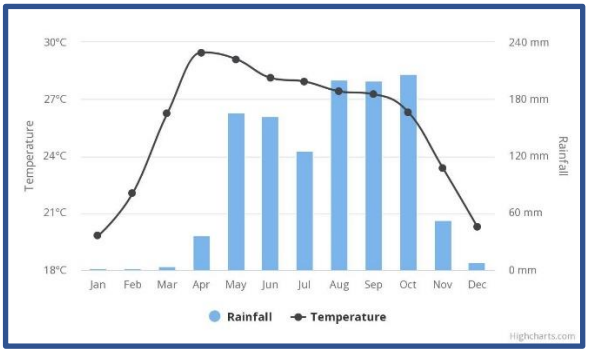
Regional Historical Annual Rainfall: +/- 2000mm
Weinert N Value <4

Chin State



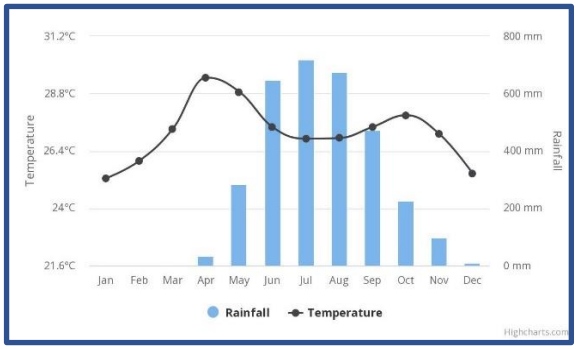
Regional Historical Annual Rainfall: +/-3100mm
Weinert N Value <4

Dry Zone (Mandalay



Regional Historical Annual Rainfall +/- 1000mm
Weinert N Value <4

Coastal Zone (Pathien)



Regional Historical Annual Rainfall +/-3100mm
Weinert N Value <4

All these zones have Weinert Climate Index of < 4 (Weinert, 1974) which defines them as “wet” in terms of pavement thickness design (Chapter 7). This index is calculated as follows:

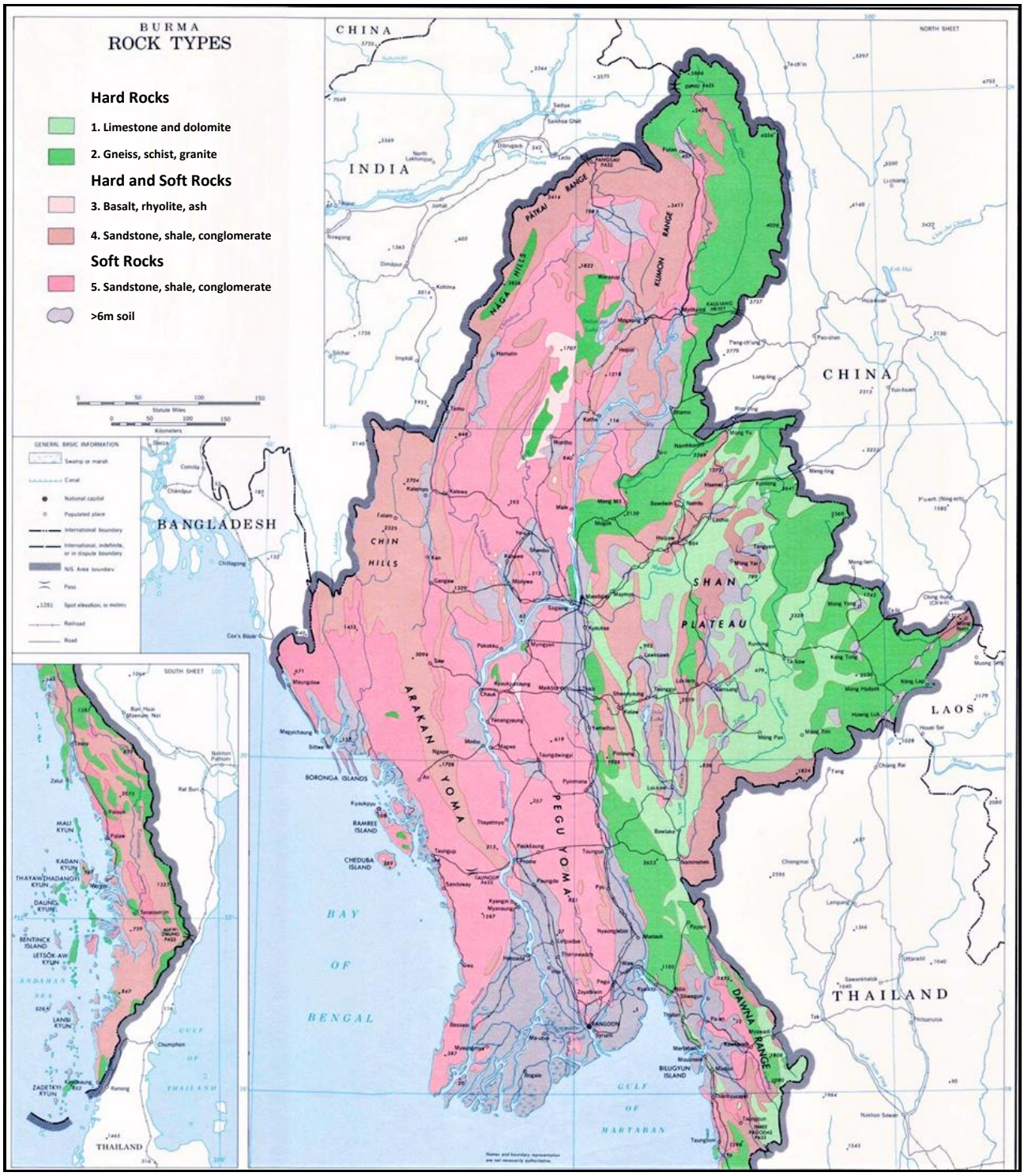
N = 12.Ej/Pa Equation B.1.1 where:

Ej = evaporation for the warmest month; Pa = total annual precipitation; N-values less than 4 apply to a climate that is seasonally tropical and wet whereas N-values greater than 4 apply to a climate that is arid, semiarid or dry.

Geology

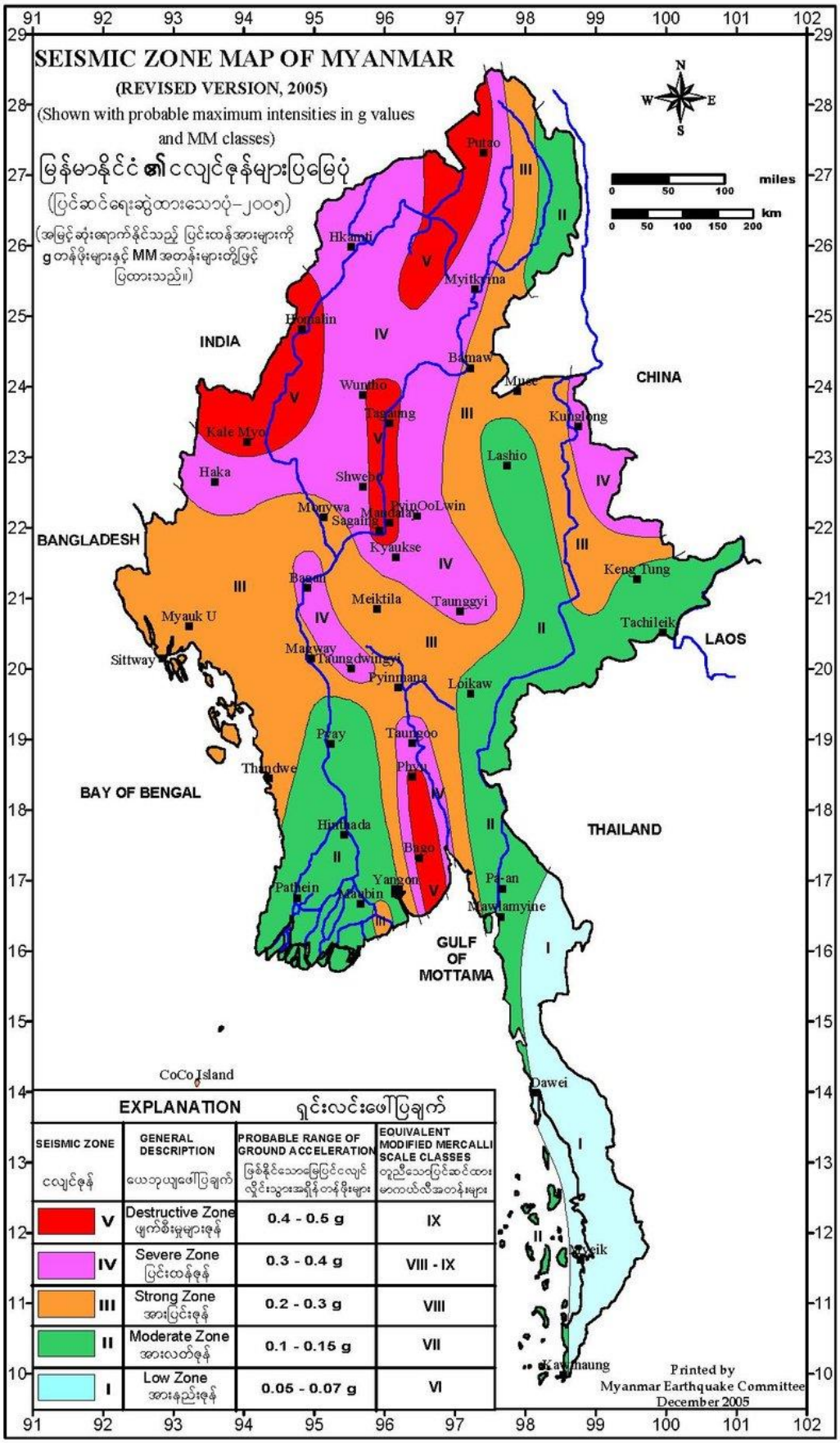
Geologically, Myanmar can be subdivided into three provinces; namely, the Western Fold Belt (WFB), the Central Lowland Province (CLP) in the middle, and the Eastern Highland Province (EHP) in the east (Hadden, 2008; Pramumijoyo, 2010). The WFB consists mostly of sequences of interbedded sedimentary rocks and a mix of basic igneous rocks. Further east, the EHP, is composed mainly of older rock groups within a complex of limestone, dolomite and metamorphic rocks. The CLP is primarily composed of alluvial materials and weak sedimentary sequences. The large active Sagaing Fault passes through the eastern margin of this province, Figure 4.4.

Figure 4.4 Myanmar Rock Types (Myanmar Geoscience Society, 2014)



A large part of Myanmar lies in the tectonically active southern part of the Himalaya and the eastern margin of the Indian Ocean, exposing parts of it to earthquake and earthquake related hazards, Figure 4.5.

Figure 4.5 Seismic Zone Map of Myanmar



Source: Revised by Dr. Maun Thein, U Tint Lwin Swe and Dr. Sone Han (December 2005)

The majority of the earthquakes in Myanmar are mainly confined to three zones (Maung Thein and Tint Lwin Swe, 2006):

1. The zone along the western fold belt of Myanmar with mostly intermediate focus earthquakes; where the earthquake frequency is much higher in the northern part.
2. The zone along the Sagaing Fault, including the offshore part in the Andaman Sea with shallow-focus earthquakes; the earthquake frequency is higher in three segments, namely (from south to north), Bago-Taungoo, Sagaing-Tagaung,and Myitkyina- Putao Segments.
3. The zone in the north-eastern part of Myanmar, which is continuous with the earthquakes in southern Yunnan, China

Figure 4.6 Myanmar's Regions & Zones

4.3 Regional Design Issues

General

Based on physical, geological and climatic criteria Myanmar is divided into eight physiographic regions or three broader zones, Figure 4.6 and Table 4.2.

Table 4.2 General Geology and Sub-grade variability

Zone	Region	Topography	Predominant Geology's	Predominant Sub-Grades
Hill-Mountain Zone	North East Mountains	Mountainous	Gneiss, granite	Weathered rock
	Shan Plateau	High rolling plateau	Crystalline limestone, dolomite	Weathered rock
	Chin-Rakhine	Mountainous	Basic igneous, strong sedimentary	Weathered rock
Dry Zone	Bago-Magwe-Mandalay	Flat-Rolling hills	Weak sandstones, shales	Sandy to weak rock
Coastal Zone	Rakhine	Flat	Coastal sediments	Sand- silt
	Ayerawaddy	Low-lying flat	Soft alluvial sediments	Silt-clay
	S. Myanmar Coast	Low lying to flat	Coastal sediments over sedimentary rock	Sand silt

Hill- Mountainous Zone

This zone lies to the east and west of the central dry zone and is characterized by a combination of hill ranges, steep river valleys and a few elevated plains. A significant proportion of the Shan hills are located within the catchment of Thanlwin River. This river with its deep gorge transects the Shan State along the north-south direction. The geology is made up by the older Cambrian to Silurian sedimentary and metasedimentary rock formations. Intruding these older rocks are granitoid rocks comprising granite, granodiorite, and diorite. Limestones and dolomites are predominant in the Shan Plateau. These rocks are inherently strong to very strong but may be weakened by weathering, faulting and fracturing.

Due to its regional structural geological setting is this region is also to subject earthquakes risk; particularly in the north-west, north east and adjacent to major Sagaing Fault. Key issues with respect to sustainable LVRR design are summarised in Table 4.3.

Table 4.3 Mountain Zone Design Issues

Issue	Impact	Design and Construction Requirements
Steep terrain	Narrow alignments and steep gradients. High cost of widening to standard designs. Roadside instability	Road safety issue focus in geometric designs. Specific geometric standards for mountain regions. Specific road designs and paving options. Possible requirement for concrete sections. Specific investigations for high cuts and embankments.
High rainfall and flash floods	Roadside instability. Erosion of embankments and bridge abutments	Flexibility in standard hydrological investigations and design approaches. Specific earthwork designs for cuts/fills. Relax geometric standards to avoid cut-to-fill cross sections as much as possible. Effective pavement, earthwork and cross drainage is essential for sustainable LVRRs in this zone.
Earthquake risk	Damage to bridge structures and high embankments. Trigger for natural landslides.	Include seismic risk factors into bridge and embankment designs. Assess risk of natural landslides in key areas.
Hard rock geology	Available rock for aggregates. Possible lack of natural sands and gravels in some areas.	Increase use of stone-based design options. Less use of natural gravel wearing course options.

Dry Zone

The Central Lowlands (Dry Zone) is bordered by the Rakhine Yoma to the west and to the east by the Shan Plateau which rises to elevation of 600 m. The topography is undulating to rolling with some slightly rugged areas. The elevation ranges from about 20 masl at Ayeyarwady River to 120 masl towards the eastern hills. The geology of the central lowlands is mostly made up of sedimentary formations consisting of massive, loosely cemented sand and erodible sandstone beds overlain by recent (Holocene) alluvial sandy loam and loamy sand. The rivers in the region are experience very high rate of sedimentation.

The Dry Zone covers more than 54,000 km^2, from lower Sagaing region, to the western and central parts of Mandalay region and most of Magway region. Situated in the shadow of the Rakhine mountain range, the Dry Zone receives limited rains compared to country averages. However, the climate is not homogenous across the area, with conditions ranging from semi-arid (and even arid) in certain areas to semi-humid in others. Dry spells during the rainy season are frequent, but their intensities vary geographically and over time. Insufficient rain is not the only potential threat, however, as decreasing forest cover and soil erosion place with a greater risk of localized flash floods during times of heavy rain.

Key issues with respect to sustainable LVRR design are summarised in Table 4.4.

Table 4.4 Dry Zone Design Issues

Issue	Impact	Design and Construction Requirements
Drought periods	Lack of water for construction activities.	Less use of water-bound macadam option in pavement layers – use of dry-bound or crushed stone option. Construction planning to avoid severest drought period.
Rolling terrain	Current alignments may be outside geometric requirements.	Localised horizontal and vertical adjustments alignment required.
Earthquake risk	Damage to bridge structures	Include seismic risk factors into bridge designs.
Heavier traffic and connectivity with national roads	Risk of high levels of commercial traffic axle overloading	Ensure projected traffic remains within LVRR design envelope. Option to design for higher axle loads. Ensure surfacing options suitable for heavier traffic.
Weak rock geology	Potential shortages of good local aggregate Erodible rock soils	Designs to make best use of limited local materials. Design costs to include for long materials hauls. Use of modification techniques for local weak rock materials. Ensure erosion protection for bridge abutments and bank protection.

Coastal Zone

The Ayeyarwady Delta is the southern extension of the central low lands, formed at the coastal reaches of the Ayeyarwady River covering an area of approximately 69,600 km^2. Much of the delta is low lying merely 3 m above sea level. Confining the delta to the west is the Rakhine Yoma and to the east by the Bago Yoma. Several distributaries of Ayeyarwady River divide the delta into islands and peninsulas.

Although the topography of the delta is seemingly flat, the topography is punctuated by subtle topographic features. These features include levees, ponds and berms associated with abandoned meanders. The abandoned meanders are easily identifiable from aerial and satellite imageries because of the arcuate form. These arcuate forms are accentuated by ponds, arcuate vegetation patterns and in some areas by roads and settlements built on the elevated levees and berms.

Subgrades are generally clay soils, often highly plastic with low strength. Although the hilly zone along the west coast of the region has gravel and stones, these are mostly sandstone with low strength. Suitable materials are found outside the delta region but require long hauling distances. Cost efficiency and maintainability would increase substantially if solutions are found to improve subgrade strength without the need for import of 'foreign' materials. Key issues with regard to LVRR design are summarised in Table 4.5.

Table 4.5 Coastal Zone Design Issues

Issue	Impact	Design and Construction Requirements
Sea Level Rise	General flooding	Raise vertical alignment; Increased bridge deck levels Modify standard drawings.
Wet tropical climate with increasing storm surges	Flooding; overtopping/erosion of embankments and bridge abutments	Soaked pavement designs Raise vertical alignment, erosion protection, use of bioengineering. Concrete pavements in key areas. Modify hydrology assessment in structure design standards Modify standard bridge standards
Lack of construction materials	Long hauls for aggregate and stone	Modify local material as much as possible; by mechanical or chemical modification. Modify standard road designs to suit materials.
Narrow embankments with canal on one side (delta area)	Restriction on widening existing tracks or class C roads Soft ground on one side of upgraded alignment	Modification to standard cross-sections. Possible use of non-standard passing-place options Design “one-side” widening options. Problems with construction diversions.
Soft Foundations (Subgrade)	Settlement of enlarged embankments	Requires site investigations. Design and construction detail to avoid differential settlement between old and new embankments..
Some local freight traffic by canal or river	Lighter traffic in some locations	Possible to allow relaxation of design and material criteria (lower CBR for base).

References

ADB, 2016. Myanmar Transport Sector Policy Note: Rural Roads and Access. Asian Development Bank. Manila

ADPC, 2012. Myanmar Action Plan on Disaster Risk Reduction [MAPDRR]. Ministry of Social Welfare, Relief and Resettlement

Cartier van Dissel S, Starkey P & Véron-Okamoto A, 2015. Republic of the Union of Myanmar: Rural Access and Road Management. ADB Transport Sector Policy Note

Department of Meteorology and Hydrology (DMH); within the Ministry of Transport and Communications

Drury LW, 2017. Hydrogeology of the Central Dry Zone, Myanmar. The Australian Water Partnership

Government of Myanmar, 2017. National Strategy for Rural Roads and Access

Government of Myanmar, 2017. Myanmar Climate Change Strategy and Action Plan (MCCSAP) 2016–2030

Hadden R L, 2008. The Geology of Burma (Myanmar): An Annotated Bibliography of Burma's Geology, Geography and Earth Science

Htwe, M.W. 2015. Country report on the status of National Soil Resources in Myanmar, http://www.fao.org/fileadmin/user_upload/GSP/docs/asia_2015/Myanmar_WinMinHtwe_MYANMAR.pdf

Maung Thein & Tint Lwin Swe, 2006. Seismic Zone Map of Myanmar, Explanatory Account. Myanmar Earthquake Committee

Myanmar Geosciences Society, 2014. Geological Map of Myanmar,s cale 1:2,250,000

Myanmar Information Management Unit (MIMU), 2019.Myanmar Physical Map

Pramumijoyo S, 2010. Report on Regional Geology of Myanmar. Gadjah Mada University, Yogyakarta, Indonesia

UNHABITAT, 2010, Manual on Earthquake Causes, Effects and Preparedness, Myanmar

UNHABITAT, 2015. Myanmar Climate Profile Climate Variabilities, Extremes and Trends in Central Dry, Coastal and Hilly Zones

UNHABITAT, 2017. Assessing Climate Risk in Myanmar; Summary for Policymakers and Planners.

Wienert H, 1974. A Climatic Index of Weathering and its Application in Road Construction. Geotechnique 24, 475-488