Mainstreaming Disaster Risk Management to sustain local roads infrastructure

Summary report

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1 Introduction

The 2017-2022 Philippine Development Plan recognizes that road infrastructure is a key point of convergence with productive sectors, but the quality remains inadequate. As of 2015, 97 percent (of 31,242 km) of national roads, 62 percent (of 15,377 km) of city roads, and 29 percent (of 31,075 km) of provincial roads were paved. The World Economic Forum-Global Competitiveness Report (WEF-GCR) 2015-2016 ranked the Philippines 97th out of 140 countries in terms of quality of road infrastructure, below neighboring countries such as Indonesia, Vietnam, Cambodia and Laos.

The KALSADA-Conditional Matching Grant to Provinces (CMGP) program was developed by the national government to help Local Government Units (LGUs) improve the quality of provincial roads, which is significantly below that of national and city roads. This program positions the national government to support, but not supplant, the provincial governments in their responsibility to provide an efficient network of provincial roads which are currently inadequate to meet the need of the population for easier mobility within the provinces. For sustainability, climate resilience considerations need to be better factored into local roads (provincial, city, municipal and barangay roads) planning and design. For local roads, LGUs typically apply adopted standards of the national roads agency, however how it is applied is largely up to the LGUs, as there is no supervision from national roads agency.

2 Objectives

The TA ‘Mainstreaming Disaster Risk Management to Sustain Local Infrastructure- A Case Study on Resilient Roads Planning’ is positioned within the context described above. Its main objectives are:

• To increase the capacity and knowledge of a selected LGU in dealing with climate/disaster risks faced by local transport infrastructure;
• To pilot an institutionalized coordination process with the national agencies to better inform local roads planning, using a learning-by-doing approach.

The pilot location is the province of Nueva Ecija. Nueva Ecija is a landlocked province in the Philippines located in the Central Luzon region, the largest island in the country. Covering a total area of 5,751.33 square kilometres, it is the largest province in Central Luzon. Its terrain begins with the southwestern marshes near the Pampanga border. It levels off and then gradually increases in elevation to rolling hills as it approaches the mountains of Sierra Madre in the east, and the Caraballo and Cordillera Central ranges in the north.

3 Approach

The scheme below shows the main steps that we advocate in order to reach the objectives of the project.
After a data gathering process it would commence with a natural hazard risk assessment. With such an assessment, hazard hotspots are identified and road sections for upgrade are prioritized. Subsequently, for each road section or hotspot, an appropriate archetype(s) is selected and an initial DMU analysis needs to be undertaken of potential measures. This would identify the promising strategic measures and prioritize them into promising adaptation pathways. Several criteria can be considered in this analysis, including effectiveness, costs and benefits. The Integrated Water Resources Management (IWRM) plan provides information on other proposed activities that should be analyzed to ascertain any interactions between the plan and the prioritized road sections and hotspots. With all information gathered, it becomes possible to perform fit-for-purpose, quantitative, strategic modelling to analyze current and future impacts of the prioritized measures of the DMU analysis and any planned IWRM measures. The initial measures prioritization and adaptation pathways can then be further detailed into preferred measures and pathways, ensuring that the impacts of future uncertainties (e.g. climate change) are considered in the analysis. A stakeholder process is needed to ensure implementation of these strategies and to discuss any impacts with them. If necessary, the entire process or specific steps can be iteratively repeated (e.g. when new data or insights arise). When all plans are made final, the ‘normal’ steps of a project need to commence, from design to construction and maintenance.

These steps have been executed in the project and are reported in two reports:
- Risk assessment report
- Adaptive strategy building report

This summary report provides the methodology, main results and recommendations of both reports.
4 Risk assessment

4.1 Data gathering
Data are critical input for any analysis. Three types of data have been identified for the risk assessment. These are hazard data, road data and traffic data.

For the hazard data a dialogue between national agencies, LGUs and the consultant has been started, which has resulted in a list of recommendations on how this process can become more effective and efficient in the future. On the one hand these recommendations are related to obtaining the data. It should be known where data are to be obtained and a fast and fluent acquisition of the data by LGUs should be ensured. On the other hand effective use of the data is advocated. Data need to be available in GIS format, quality of the data need to be verified, datasets need to conform to standards and a proper background information needs to be provided with the data. The development of the GeoRiskPH portal by DOST-PHIVOLCS will address many of these recommendations.

The road data have been obtained using the RBIS (Roads and Bridges Inventory System). The RBIS provides a wealth of information. However, to be utilized effectively, the data should be more reliable and accurate and validation of the data by the LGUs is necessary and highly recommended.

The traffic data have been obtained from counts that have been performed by the LGU. It took however large efforts to be able to convert the traffic counts into useful information for the risk assessment. Therefore recommendations have been provided on the traffic survey formats, the counting process itself and one the processing of the data obtained.

4.2 Approach and results
The project is focused on the provincial road network of Nueva Ecija with a focus on three natural hazards being flooding, landslides and earthquakes. For flooding and earthquakes detailed hazard maps have been obtained with threat levels (expressed in respectively meters of water and Peak Ground Acceleration) at different return periods. For landslides a detailed susceptibility map has been obtained. This could however not be used in the risk assessment since it lacks the characterization of the hazard level in terms of the size/run-out of the landslides and the respective probabilities of occurrence.

Given the objective to mainstream Disaster Risk Management to sustain local infrastructure, it was the challenge to use the available existing information in such a way that an LGU should be able to perform the analyses themselves. In that sense no new hazard assessments have been undertaken. Also, the risk assessment is only undertaken for the current climate. Furthermore, the risk assessment has been undertaken using the following elements
1 Collection of data to perform the assessment related to the hazards, the road itself and traffic
2 Calculating exposure of the road network for the different hazards
3 Calculating the consequences, expressed in
3.1 Damages to the road
3.2 Losses for the users of the road
4 Evaluation of the risk
These elements have been derived from the UNISDR framework of risk that is schematically shown in Figure 4.1. Since we are investigating the risk for roads, we need to consider vulnerability in greater detail which can be explained with Figure 4.2. In this context, we apply the term vulnerability for gaining an understanding of the degree of physical damage to the road which scope is under the jurisdiction of the LGU. The damages are expressed in monetary terms. Furthermore, we apply the term ‘losses for road users’ together with the term criticality, when the road is not functioning as it is constructed for. These are outside direct influence of the LGU, but within the primary objective of having road infrastructure which is to serve society. Also the losses are expressed in monetary terms.

Damages and losses are calculated for the various return periods for which the hazard intensity is known. Critical input in this respect are the estimates of repair costs (for damages) and duration of the interruption of the road (for losses) after a certain threat level. We consider it very important to base these estimates on local experiences and circumstances and have therefore made an inventory of factors that can be used using information on real past events and assumptions made by the provincial engineering office. By combining all road information, exposure data, traffic data and the estimates on repairs and duration it has become possible to calculate the damages and losses for every RBIS road in monetary terms (Pesos). The entire risk assessment process is visualized in maps.

The tables below summarize the results on expected damages and losses for the total network. It may be seen that in general, damages and losses are increasing with an increasing return period and corresponding threat level. It is to be noted that no judgement or recommendation on design requirements is made based on these calculated total damages and losses.

<table>
<thead>
<tr>
<th>Return period (years)</th>
<th>Damage (Million Pesos)</th>
<th>Losses (Million Pesos)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>1866</td>
<td>575</td>
</tr>
<tr>
<td>25</td>
<td>3359</td>
<td>587</td>
</tr>
<tr>
<td>100</td>
<td>4377</td>
<td>587</td>
</tr>
</tbody>
</table>


Table 4.2. Total network damage per earthquake hazard map.

<table>
<thead>
<tr>
<th>Return period (years)</th>
<th>Damage (Million Pesos)</th>
<th>Losses (Million Pesos)</th>
</tr>
</thead>
<tbody>
<tr>
<td>500</td>
<td>2933</td>
<td>458</td>
</tr>
<tr>
<td>1000</td>
<td>3577</td>
<td>605</td>
</tr>
<tr>
<td>2500</td>
<td>4297</td>
<td>605</td>
</tr>
</tbody>
</table>

Risks are then calculated by combining the return period (likelihood) and the calculated damages and losses. This results in the calculation of annually to be expected damages (EAD) and losses (EAL) which are presented in Table 4.3. It is observed that the total expected annual costs, given by the sum of EAD and EAL per hazard is significantly larger for floods than for earthquakes. Furthermore, the EAD are both for floods and earthquakes significantly higher than the EAL. This highlights the importance of accurately estimating costs associated with damages and losses for different scenarios, particularly if a fully integrated multi-hazard approach to the prioritization of measures is used. Otherwise, it may lead to having certain hazards disregarded.

Table 4.3. Summary of EAD and EAL per hazard, expressed in Million Pesos

<table>
<thead>
<tr>
<th>Hazard</th>
<th>EAD</th>
<th>EAL</th>
<th>Total (EAD+EAL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floods</td>
<td>533.99</td>
<td>110.60</td>
<td>644.6</td>
</tr>
<tr>
<td>Earthquakes</td>
<td>5.81</td>
<td>0.97</td>
<td>6.78</td>
</tr>
</tbody>
</table>

The aim of the risk evaluation and prioritization is to rank the roads from an action perspective. The top priority corresponds to roads that are both expected to sustain the highest damage costs and where the disruption will lead to the largest losses. At the bottom of the prioritization ranking are the roads with the smaller expected damages and disruption losses. The contribution of damages and losses for prioritization, however, is not necessarily linear. Because the EAD are significantly larger than the monetized quantification of EAL, a simple sum of the values would dilute the importance of minimizing the losses for the road users. As such, we propose the use of a prioritization matrix. After application of the matrix prioritization maps have been compiled. One example for floods is presented in

![Prioritization matrix for identification of hotspots](image-url)
4.3 Recommendations

The use of the results may be divided in two main direction:

1. For use in planning and asset management
   The results of the risk assessment can provide arguments for the planning process in the province. The prioritization maps as well as the EAD and EAL maps can be used in this respect in order to identify road segments that are to be experiencing high damages and/or losses. The exposure maps may then be used to identify specific locations on these segments that should be analysed for further action. In that sense, the risk assessment serves as input for the definition of adaptation strategies that are discussed in a separate report.

2. For use in emergency situations
   During an emergency situation many decisions need to be made in a short period of time. The risk assessment provides a wealth of information that can be used for that purpose. Exposure maps can be consulted to identify likely locations that will be affected by intense rainfall leading to flooding and/or landslides. The losses maps provide input which of the exposed roads are expected to experience the highest impact for its users and are therefore the most critical. This is valuable information for preparatory measures, as well as decision on where to go first for response actions after an event. The damages maps provide valuable information for first rough budget estimates for repair and reconstruction allowing for fast fund raising.

Figure 4.4 Prioritization map for floods
In general, it can be highlighted that:

- Having accurate and complete mapped information is central for the quality of the results of the risk assessment; this includes having hazard maps with return periods, the road network and assets such as bridges and culverts and the traffic information.
- A good communication with national agencies and appropriate channels for the exchange of information is most valuable. A process of alignment between national agencies, DILG and LGUs has already started and needs to be continued in order to enhance the data gathering process.
- Good Geographic Information Systems capabilities are essential for maintaining and validating information and run the risk assessment analysis. With this respect we refer to a training program currently being undertaken/launched by NAMRIA and DILG expressly designed to build LGU GIS capacity.
- Inventoried data for the estimation of infrastructure damage and disruption times and costs is essential for the realistic quantification of the damages and losses. We have made first steps in this regard, but highly advocate to further improve the damage and duration estimates by starting a proper monitoring of events in a database. Such a database should consist information of the following:
  - The type of hazard occurring
  - Exposure data (flood depth, PGA, amount of volume of landslide)
  - Road characteristics of the exposed road (embankment, culvert/bridge, road condition, maintenance status)
  - Recorded damages in short description
  - Repair costs expressed in Pesos
  - Duration of the event

It is important that the database will include all situations of impacted roads; also when no or very little damage is to be reported. It may be the case that the current numbers for floods are based on high damage events only, leading to possibly too high vulnerability estimates.

- The evaluation of risk and the prioritization of roads for interventions should be defined in consultation with the relevant stakeholders to reflect the most important issues for decision-making.

With the availability of information and training of personnel, the approach can be scaled and/or replicated in other provinces by the respective LGUs, especially in combination with consultants. During a workshop in which results of the TA were presented and the LGUs have used the methodology in hands-on exercises it became clear that the approach itself is generally understood and LGUs are able to use the results. Therefore, we consider LGUs at least capable of procuring these kind of assessments to consultants.

While DILG is planning for the implementation of the approach in all provinces, it seems to be advisable to first select a few LGUs that are yet planning to update their local infrastructure plans with the support of consultants. The methodology and approach can then be provided to the consultants for possible use and further learning by doing. After a successful application by these first adopters together with additional lessons learned, the methodology may then be implemented in the rest of the country. UNDP, which is a DILG partner in the capacity building process, is expected to assist DILG in future efforts on LGU capacity building and could also be aligned in the above mentioned process.
5 Adaptive strategy building

5.1 Initial prioritisation of measures following DMU principles

5.1.1 Approach
Decision makers today face deep uncertainties about future conditions. They need to be confident the decisions they take today will continue to apply in the future. The adaptive strategy building approach applied in this (Figure 5.1) contextualises and adapts Decision-Making Under Uncertainty (DMU) principles to the specifics of provincial roads planning in Nueva Ecija. We propose a semi-quantitative assessment, whereby available data and expert judgement is combined in a procedure intended to be appropriate for LGU roads planners to implement independently.

The analysis is presented at the level of generic archetypes, with the current and future performance of measures relevant to each archetype assessed via expert judgement. Impacts of both climatic and socioeconomic uncertainties are included in the analysis, through examination of existing trends and projected developments in expected peak discharges and traffic demand. The robustness of individual measures across several plausible future scenarios is assessed through minimax analysis, with measures ultimately prioritised and assessed semi-quantitatively using a flexible, weighted multi-criteria analysis framework. Prioritised measures are then be used to assemble initial relative adaptation pathways through consideration of the sequencing of options in the short-, medium- and long-terms. Stakeholders should be involved at every step to inform the qualitative scoring procedures employed during each step. We refer the reader to the main Adaptive Strategy Building Report for further details.
5.1.2 Archetypes
In applying the approach, we identify and analyse seven (7) key road archetypes relevant to the different hazards considered in this TA. Where relevant, hazards are further split into multiple archetypes relevant to their key characteristics, such as flow direction, existing infrastructure, or geological conditions. The intention of the archetypical approach is to build on the outputs from the risk assessment (refer Chapter 4). Provincial roads planners should first determine key ‘hotspot’ locations for intervention from the risk assessment. For each hotspot, they could then select the appropriate archetype to inform an initial assessment of potential measures and their prioritisation.

5.1.3 Key uncertainties and their future impacts
The analysis considers two key drivers of uncertainty: the effects of climate change on future peak river flows and potential growth in traffic demands. Analysis of these uncertainties reveals a large plausible range of both future climate impacts and traffic demands in Nueva Ecija in 2050, with these leading to potential increases in damages and losses respectively between 0-40% and 200-400% above present levels (Figure 5.2).

5.1.4 Measures assessment and evaluation
Stepping through the analysis procedure generates scoring tables such as those provided overleaf in Figure 5.3. The final outcome is the prioritised set of adaptation options against the weighted criteria of interest. Six criteria have been considered in this TA (cost, effectiveness, robustness, flexibility, ease of implementation, maintenance and durability), however the methodology has been kept intentionally flexible such that planners can add/remove criteria (e.g. environmental impact, social impact, etc.) should LGUs (or their stakeholders) choose to do so.

Note that the presented assessments must be seen as a starting point, rather than the definitive solution. The generic assessment tables provided should be adapted and contextualised by LGU planners to the specific local conditions of each road section, together with key stakeholders. Guidance is provided in the report regarding how to best go about this.
### Step 2 – Measures effectiveness

<table>
<thead>
<tr>
<th>Measure</th>
<th>Risk reduction in Damages (D) or Losses (L)</th>
<th>Effectiveness (Risk reduction, %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retention Basin or Flow Diversion</td>
<td>D,L</td>
<td>100%</td>
</tr>
<tr>
<td>Elevate roads (with culverts/bridge/causeway/ford) (inc. erosion protection)</td>
<td>D,L</td>
<td>80%</td>
</tr>
<tr>
<td>Submersible road (inc. erosion protection)</td>
<td>D</td>
<td>60%</td>
</tr>
</tbody>
</table>

### Step 3a – Future performance of measures

<table>
<thead>
<tr>
<th>Measure</th>
<th>Performance in 2050</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High CC</td>
</tr>
<tr>
<td>Current Situation (no measures)</td>
<td>1</td>
</tr>
<tr>
<td>Retention Basin or Flow Diversion</td>
<td>5</td>
</tr>
<tr>
<td>Elevate roads with culverts/bridge/causeway/ford (inc. erosion protection)</td>
<td>4</td>
</tr>
</tbody>
</table>

### Step 3b – Robustness of measures

<table>
<thead>
<tr>
<th>Measure</th>
<th>High CC</th>
<th>Low CC</th>
<th>Robustness Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High Traffic</td>
<td>Low Traffic</td>
<td>High Traffic</td>
</tr>
<tr>
<td>Retention Basin or Flow Diversion</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Elevate roads (with culverts/bridge/causeway/ford) (inc. erosion protection)</td>
<td>0.80</td>
<td>0.80</td>
<td>1.00</td>
</tr>
<tr>
<td>Submersible road (inc. erosion protection)</td>
<td>0.20</td>
<td>0.40</td>
<td>0.40</td>
</tr>
<tr>
<td>Install upstream weirs to decrease flow velocity</td>
<td>0.20</td>
<td>0.40</td>
<td>0.40</td>
</tr>
<tr>
<td>Erosion protection (vegetation, synthetics, gabions, concrete, etc.)</td>
<td>0.20</td>
<td>0.40</td>
<td>0.60</td>
</tr>
<tr>
<td>Traffic management (re-routing)</td>
<td>0.20</td>
<td>0.40</td>
<td>0.40</td>
</tr>
<tr>
<td>Increase response and recovery capacity (inc. crews, materials, equipment)</td>
<td>0.20</td>
<td>0.40</td>
<td>0.40</td>
</tr>
<tr>
<td>Increase redundancy (improve barangay road(s))</td>
<td>0.80</td>
<td>1.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>

### Step 4 – Measure prioritisation

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Cost</th>
<th>Effectivenesss</th>
<th>Robustnesss</th>
<th>Flexibility</th>
<th>Implementation</th>
<th>Maintenance</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weighting</td>
<td>10%</td>
<td>50%</td>
<td>10%</td>
<td>8%</td>
<td>4%</td>
<td>2%</td>
<td>4.7</td>
</tr>
<tr>
<td>Retention Basin or Flow Diversion</td>
<td>1</td>
<td>10</td>
<td>10</td>
<td>8</td>
<td>1</td>
<td>4</td>
<td>4.7</td>
</tr>
<tr>
<td>Elevate roads with culverts/bridge/causeway/ford (inc. erosion protection)</td>
<td>3</td>
<td>8</td>
<td>9</td>
<td>6</td>
<td>4</td>
<td>7</td>
<td>5.3</td>
</tr>
<tr>
<td>Submersible road (inc. erosion protection)</td>
<td>6</td>
<td>6</td>
<td>4</td>
<td>8</td>
<td>7</td>
<td>8</td>
<td>6.2</td>
</tr>
<tr>
<td>Install upstream weirs to decrease flow velocity</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>7</td>
<td>6</td>
<td>8</td>
<td>4.6</td>
</tr>
<tr>
<td>Erosion protection (vegetation, synthetics, gabions, concrete, etc.)</td>
<td>5</td>
<td>6</td>
<td>5</td>
<td>9</td>
<td>8</td>
<td>8</td>
<td>6.1</td>
</tr>
<tr>
<td>Traffic management (re-routing)</td>
<td>10</td>
<td>2</td>
<td>4</td>
<td>10</td>
<td>9</td>
<td>10</td>
<td>7.1</td>
</tr>
<tr>
<td>Increase response and recovery capacity (inc. crews, materials, equipment)</td>
<td>8</td>
<td>3.5</td>
<td>4</td>
<td>10</td>
<td>8</td>
<td>8</td>
<td>6.5</td>
</tr>
<tr>
<td>Increase redundancy (improve barangay road(s))</td>
<td>1</td>
<td>8</td>
<td>10</td>
<td>8</td>
<td>2</td>
<td>5</td>
<td>4.2</td>
</tr>
</tbody>
</table>

*Figure 5.3: Example assessment for the Perpendicular Flow – No Drainage archetype*
5.2 Review of IWRM Plan

5.2.1 Approach

Integrated Water Resources Management (IWRM) promotes the coordinated development and management of water, land, and related resources in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems. The Philippines recently adopted guidelines for IWRM planning to be implemented in the river basins in the country. These are currently in the process of being adopted in individual river basins, with an important part of this process being capacity development of Local Government Unit (LGU) officials regarding their application.

The purpose of this component of the TA was to ascertain the compliance of present IWRM plans for the Pampanga River Basin (PRB) with these guidelines and to determine the implications of relevance of these plans (if any) for provincial roads planners in Nueva Ecija.

5.2.2 Results

Compliance with National IWRM Framework

Although each of the two planning documents do not fully comply with the new guidelines, they did undertake many of the required activities presented in the updated analytical framework. Future updates to the plans would benefit from more structured, quantitative analysis procedures including the development of an appropriate computational framework and specification of measurable performance criteria and indicators against which the formulation and performance of the plan may be assessed. Similarly, adaptive planning principles should be incorporated, alternative strategies developed and evaluated, and a formal monitoring framework formulated to measure the overall performance of the plan against the specified performance criteria. We refer the reader to the main Adaptive Strategy Building Report for further details.

Implications for provincial roads planning in Nueva Ecija

For the purposes of this TA we analysed the implication of any structural flood mitigation, hazard management and climate adaptation measures identified in the IWRM plan. Many of the measures identified in the plan are in downstream areas of the PRB and would therefore not impact roads in Nueva Ecija. Projects of relevance to Nueva Ecija, include:

• Rehabilitation and strengthening of ring levees (e.g. in Arayat-Cabiao)
• Dredging and widening of critical river sections, construction of river training works, dikes and flood levees (e.g. for Rio Chico)
• River training works and slope stabilization of other rivers (e.g. Coronell, Talavera)
• Construction of segments of the North Luzon East Expressway and other highways
• Road widening and embankment heightening, provision of drainage systems for existing expressways and other roads

Unfortunately, minimal information was made available regarding any of these proposed measures (e.g. precise locations, dimensioning, or their intended impacts or consequences) to facilitate further assessment in this study. In general, it can be stated that flood control projects that propose installing flood control structures, or dredging, widening and training river channels are intended to lower water levels at vulnerable (road) locations. Similarly, dike and levee construction/rehabilitation are intended to protect presently vulnerable areas from future incidences of flooding. As such, they hold significant implications for maintaining road passage during peak flow events. Conversely, flood control and road improvement projects such as the construction of new roads, widening existing roads or elevating them on embankments, installing bridges, fords and the like will inevitably impact flow patterns throughout the
floodplain. Elevating roads on embankments where previously water could flood unimpeded often merely shifts the impacts of flooding elsewhere. This can be very effective if the locations of these new structures have been well thought through and subjected to rigorous social and environmental impact assessment. However, in the absence of such analyses, these actions can lead to unintended negative consequences.

Further information on the proposed measures is therefore required to facilitate further analysis of their implications (if any) for provincial roads planning.

5.3 **Fit-for-purpose strategic modelling**

5.3.1 **Approach**

The TA also investigated the potential and provided guidance to LGU planners regarding how to undertake simplified, rapid, quantitative analyses of provincial road vulnerability to flood hazards to better inform their own planning. This would elaborate and refine the outputs from the initial prioritisation of measures established previously (refer section 5.1). Naturally, it is advised that any already planned IWRM measures from the preceding section should also be incorporated into these analyses; however, this was not possible in this TA given the lack of available data. A demonstrative, example analysis is therefore presented, utilising simplified flood models at two scales, populated with readily available local and/or global data, and comparing a limited portfolio of three adaptation measures. Simplified metrics are assessed – the anticipated depth of flow and velocities acting on affected road sections – to ascertain the impacts of example strategic options for hazard mitigation under various current and future peak discharge conditions. We refer the reader to the main Adaptive Strategy Building Report for further details.

5.3.2 **Results**

The modelling study indicated the value of undertaking simplified, rapid quantitative analyses to investigate flood impacts – provided that the analytical boundary conditions and input data are sufficiently reliable. These types of models can be effectively used to demonstrate orders of magnitude for the relative mitigation effects of a variety of strategic options relevant to roads planners. Moreover, potential future flood impacts resulting from climate change can be quickly assessed to ensure that any LGU interventions are made robust and resilient to the uncertain future.

However, the study also revealed two key limitations of the analysis. First, the reliability of the topographic input data meant that some vulnerable locations could not be effectively analysed. Second, the simplification of the model via the removal of smaller tributaries, creeks and canals was often seen to exclude several causes of vulnerability from the analysis. Hence, any models applied in these types of assessments must be fit-for-purpose. They must have both reliable and accurate input data and operate at the scale(s) of the processes driving vulnerability and the measures to combat these. Simplified models will often work to assess measures and impacts operating at larger scales, however, more detailed models may be required to assess impacts at the scale of vulnerable ‘hotspots’. Physical site visits to vulnerable locations (to gain a richer understanding of the actual problems needing to be addressed) can help avoid these limitations by improving model conceptualisation prior to any modelling work being carried out.

5.4 **Implications for Design Standards**

The availability of design and construction standards for local roads and drainage facilities, and how they are being applied by LGU engineers and contractors, is of key importance to be able to improve the disaster risk management for local infrastructure. We have provided an overview
on the available design and construction standards, the way these are being applied and understood at the local level and recommendations on how the capacity of LGUs and local contractors can be enhanced in this respect.

DPWH, sets the standards for design and construction that the consultants, contractors, and LGUs follow for building infrastructures in the country. It has become clear that the Local Government Unit of Nueva Ecija also applies this in their projects for design and construction of roads. The Detailed Engineering Design is however always done by external Consultants. For maintenance of infrastructures like bridges and roads, LGUs have their own process which is not particularly set by DPWH.

In relation to managing disaster and climate risk however, the standards are not particularly used in practice. In general the LGU uses a rather reactive approach that once a flooding has occurred mainly elevation of the road is considered. We have provided recommendations on how this may be improved and also refer to the methodology as proposed in the previous paragraphs.

The DPWH standards do consider climate change to some extent. However, some specific recommendations have been made in this respect. This is:

• to explicitly describe how an increase in rainfall intensity needs to be used in the design of new and evaluation of existing road assets;
• to consider uncertainty towards the future together with the time horizon for the design that is to be made
• to also consider climate change in relation to landslides
• to reconsider the design requirements in terms of return periods for smaller creeks, tributaries and overland flow. These seem to be the major cause for local roads flooding and are not properly addressed in the DPWH standards that are written for the national roads

5.5 Key conclusions and recommendations

5.5.1 General

With the availability of information and training of personnel, we believe the approaches and methodologies described in the Adaptive Strategy Building report can be scaled and/or replicated in other provinces. Given the somewhat complex nature of the methodologies proposed, we advise that LGUs planning to update their local infrastructure are selected by DILG to undertake these activities together with the support of local consultants. These reports may then be provided to the consultants for possible use and further learning by doing.

Key conclusions and recommendations specific to each of the preceding sections are outlined below. Additional detailed conclusions and recommendations are provided in the Adaptive Strategy Building Report.

5.5.2 Adaptive strategy building approach

When undertaking DMU analyses, it is important to consider both the dynamics of decision-making through time (i.e. pathways) and to recognise the full plausible range of potential futures. For Nueva Ecija, the large envelope of future uncertainty means its roads planning must be dominated by flexibility in order to effectively adapt to the conditions as they change. LGU roads planners need to be careful not to implement measures that prevent other actions in the future (i.e. create ‘lock-ins’). Key recommendations in relation to the application of the approach are:
1. The semi-quantitative approach offers an easy means for LGU planners to better account for future uncertainties in their roads planning. DILG should ensure that supported application and capacity building is carried out with targeted LGUs, supported by consultants as necessary. This could be followed up by a wider DILG-coordinated capacity building program for remaining LGUs to support wider approach roll-out and build confidence in approach application. Local consultants could be included in capacity building activities to ensure adequate support exists for the LGUs in the future.

2. An important aspect of the approach is the contextualisation of the generic archetypical assessments to the specific local conditions for each vulnerable road section. The assessment tables and approach have been designed with flexibility in mind: values can be changed, and new measures may be introduced or others omitted. We recommend that LGU planners and local consultants familiarise themselves with the approach such that independent contextualisation is not seen as a barrier to its application. The capacity building approach outlined in the preceding recommendation should therefore include a focus on this integral element of the approach.

3. When formulating long-term adaptive strategies, LGU roads planners must also determine and keep in mind the overall policy objectives for each road section. Again, the proposed capacity building approach should focus on how LGU practitioners can best do this given locally available information.

5.5.3 Review and incorporation of IWRM into planning procedures

IWRM plans will impact provincial roads planning and vice versa. LGU planners must therefore become more involved in river basin IWRM planning processes; not only to become better informed about any planned measures, but to also provide them with opportunities to inject their knowledge, perspectives and priorities into these processes and to deliver better integrated outcomes for the PRB as a whole. Considering the integrated impacts of roads and hazard reduction measures will assist LGU planners implement measures which are more robust and resilient to these impacts under both present-day and uncertain future conditions. Key recommendations in relation to this component of the TA are:

1. NWDB, and NEDA should coordinate to update the existing PRB IWRM plan to address the shortcomings identified as a result of this review. An improved structured quantitative analysis procedure should be carried out, including the specification of measurable performance criteria and indicators against which the formulation and performance of the plan can be assessed. Quantitative base and reference case analyses should be conducted against these criteria, in addition to impact assessment of potential measures and strategies. Scenario analyses should be elaborated to account for the plausible range of future climatic and socioeconomic uncertainties. Alternative strategies should be developed, from which a preferred strategy can be selected and elaborated in consultation with stakeholders. A formal monitoring framework should be formulated to measure the overall performance of the plan against the performance criteria. LGU planners must ensure they are involved in these processes to ensure that metrics and measures to assess and improve provincial roads resilience are included in the plans. Appropriate consultants should be engaged to support these processes as and when required, with terms of reference including requirements for comprehensive capacity transfer to local organisations.

2. Road planning at all levels of government must be aligned with one another to facilitate coordination and commonality of purpose. DPWH should formally engage LGUs in its FRM,
DRR and roads planning processes to ensure proposals will enhance provincial
development objectives. LGUs must ensure that their roads plans reinforce existing
regional and national priorities and comply with the overall objectives of the PRB IWRM
plan. DPWH and LGUs must take joint strategic decisions based on an assessment of the
comparative integrated impacts of different actions.

3. LGU roads planners must liaise and coordinate with DPWH to obtain additional information
pertaining to the measures proposed in the existing IWRM plan (i.e. locations, likely
dimensions, intended impacts, etc.). Should this information not yet exist, LGUs should
request to be involved in future planning activities relating to these measures in which such
information will be determined/become available. This will allow LGUs to better incorporate
the intended impacts of these measures into their own planning activities and facilitate
improved LGU investment prioritisations to improve the resilience of the provincial road
network as an integrated whole. DILG and DPWH have a significant role to play in
facilitating and coordinating LGU involvement in these processes.

5.5.4 Fit-for-purpose strategic modelling
We cannot overstate the value of fit-for-purpose quantitative modelling when undertaking rapid
strategic assessments. This means modelling that is performed at the appropriate scale and
resolution for the hazard and the mitigation measures to be represented. Key recommendations
stemming from these conclusions are:

1. LGUs should (engage others to) undertake fit-for-purpose, rapid, quantitative analyses
of the integrated impacts of their plans to support the planning process. These provide an
effective demonstration of the orders of magnitude of the impacts of (flood) hazards and
measures to mitigate these. Note that fit-for-purpose modelling is imperative. Modelling
must be performed at the appropriate scale and resolution for the hazard and the mitigation
measures to be represented. Such analyses also need to be followed up with more detailed
studies at higher levels of detail in an iterative assessment and design process. Appropriate
consultants should be engaged to support these analyses as and when required.

2. Quantitative modelling studies should be informed by physical site visits to vulnerable
locations to guarantee a complete picture of the challenges to be addressed is obtained.
The type of data to be collected is location-specific, but with respect to roads flooding could
include: the current condition of road assets, their existing elevation in relation to the
surrounding area, a qualitative assessment of area hydrology (likely flow/drainage paths),
other drivers of vulnerability, and other such information. We recommend LGUs (or their
engaged consultants) carry out these inspections at the time of the assessment, to ensure
that up-to-date information can be incorporated into the modelling analyses.

3. A critical piece of information informing flood modelling studies is the accuracy of the
topographic data applied. The local and global data sets applied in this study were of
insufficient resolution to permit meaningful analyses of all vulnerable road locations (e.g.
perpendicular river crossings). We recommend DILG, in consultation with NAMRIA and
MGB, identify improved sources of topographic information for LGUs, which could be
obtained either through coarse physical surveying of affected areas or improved remote
sensing (e.g. LiDAR).