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Developing Criteria for Priority Ranking of Bridges Construction: A Case Study of Bagmati Province, Nepal

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Abstract

Prioritizing the implementation of projects is seen as being of great importance after the institutionalization of federalism. Federal, provincial, and local governments execute infrastructure development in their jurisdiction. This study identifies criteria for federal, provincial, and local governments to select bridges based on the prevalent practice of multi-criteria prioritization on the bridge sector at the national and international levels and discussions with officials from organizations like DOR and LRBP. Sub-criteria are developed using secondary data on traffic, population, cost of the bridge, and all-weather road length, as well as multi-criteria analysis techniques like linear value function, series of verbal pairwise assessments, and direct rating. AHP analysis assigned weights to criteria with input from 12 professionals, including elected representatives and experts in the bridge sector. Three criteria for the federal level, five for the province level, and four for the local level are identified. Among the three criteria for the federal level, the strategic importance of road weighs 58.1%, AADT weighs 28.4%, and project readiness weighs 13.5%. For the province-level matrix, strategic road importance weighs 34.3%, access to socio-economic activities weighs 22.9%, all-weathered road length weighs 16.6%, present traffic volume weighs 14.9%, and per capita investment weighs 11.3 %. Local-level criteria highlighted the most significant road closure duration (34%). While additional criteria were suggested, they were not measurable due to data limitations. The matrix developed from this study provides a valuable reference for bridge project prioritization and can guide public authorities in making more effective decisions.

Keywords: Federalism; Bridge project prioritization; Multi-criteria analysis (MCA); Analytic Hierarchy Process (AHP)

1. Introduction

Federalism gets institutionalized in the country, dictating unequal development within all parts and regions under regionalism and a unitary system of government. Central, province, and local governments have been formed to conduct development activities within their jurisdiction. Roads and bridges are integrated to develop any locality. Due to bridges' critical role, there is a significant demand for their construction. However, the current selection process for bridge projects is often arbitrary, influenced by political factors, and lacks scientific rigor and transparency. Given the limited development funds in our country, it is essential to adopt a well-planned and prioritized investment strategy to maximize the effectiveness of the available resources and budget. Furthermore, after the establishment of federalism, prioritizing infrastructure projects is seen as highly important. It has been recognized as one of the significant factors that prevent the selection of sub-optimal projects and can efficiently allocate scarce funds to maximize socio-economic benefits.

Before Nepal's federal system, road and bridge construction was handled by different government bodies: the Department of Roads (DoR) managed national highways and feeder roads, the Department of Local Infrastructure Development and Agricultural Roads (DoLIDAR) focused on rural roads, and municipalities were in charge of urban roads. Each operated independently within its jurisdiction. The federal system restructured these responsibilities. With the introduction of federalism came federal capital, new provinces, and local levels, which were non-existent earlier. Consequently, the name given to road links and their importance level has started to be seen uniquely. For example, the road joining the federal and province headquarters came into existence. Some earlier national highways/ feeder roads seen with lesser importance previously might become more important as they connect two newly declared higher-importance administrative units. In the meantime, comprising primarily of bureaucrats and officials from the previous system, the new administrative bodies were

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formed whose roles, responsibilities, and jurisdiction varied significantly in one way or another. While the federal level emphasizes more strategic roads and nationwide connectivity, the provincial government is responsible for easier access and better networks within the local levels inside the province, and local levels focus on the roads within its area and agricultural roads. Moreover, for the transportation sector, the responsibility for national transportation policies and management of railways and national highways to the federation is mentioned in Schedule 5 of the Constitution of Nepal. Similarly, the responsibility of Provincial Highways is assigned to provinces as mentioned in Schedule 6 of the Constitution. Though Schedule 7 does not speak directly on the transportation sector, federation, and province are provided concurrent powers on tourism, poverty alleviation, industrialization, employment, industries, mines, and physical infrastructures. Similarly, the responsibility for local, rural, and agro roads is assigned to the local level as mentioned in Schedule 8.

This study was carried out for two main reasons. The first reason is that though DOR and the Department of Local Infrastructure (DOLI) possess multi-criteria analysis (MCA) priority tools for prioritizing new bridges for implementation, the scope of both organizations has shifted due to the introduction of federalism in the country. Three levels of government (federal, provincial, and local) are now constructing bridges in their respective jurisdiction. DOR is implementing bridges at the federal level. In contrast, DOLI, Transport Infrastructure Directorate (TID), and Infrastructure Development Office (IDO) work at the provincial level, while the municipality and rural municipality offices work at the local level. Secondly, despite being present in some form or other in both departments, the prioritization mechanisms are ineffective. Though the Bridge Management System is operational in DOR, its effective use for project prioritization has not been exercised. Similarly, the Local Roads Bridge Program (LRBP) uses a three-stage screening system (minimum, local/district, central) for bridge selection and prioritization. One of the minimum conditions for bridge selection is that bridges to be constructed must lie on the District Road Core Network (DRCN). However, several bridges have been allocated a budget and are being implemented, though they do not fulfill this condition. Hence, the use of the existing priority matrix needs to be aligned with the needs of each level of government and modified for its practical application in the bridge selection process.

This study aims to identify criteria for bridge selection by federal, provincial, and local governments, developing sub-criteria and deriving weights for these criteria to prioritize bridge project selection. Although consultations with officials from DOR and LRBP informed the criteria selection, the final choices were somewhat ad-hoc, relying heavily on existing matrices. A workshop or conference to achieve consensus on the criteria would have enhanced the robustness of this study, but time and financial constraints prevented this from occurring. Despite this limitation, this study is an important starting point for developing a multi-criteria tool for bridge prioritization.

2. Literature Review

Since 1990, Nepal's democracy has seen multiple parties emerge, but none have achieved strong federal governance. Political leaders' centralized control and a focus on personal gains over public welfare hinder democratic progress. Nepal's future may improve if democratic reforms are paired with economic growth, creating a more inclusive and accountable system, but without these changes, prospects remain uncertain (Sharma, 2020). Enhancing federalism and decentralization strategies should include transparent decision-making, alignment of policies across government levels, updates to legal frameworks related to federalism, and the creation of indicators and benchmarks for evaluating governance and service delivery (Pokharel, 2024).

The choice of bridges for construction is primarily influenced by political agendas, resulting in projects that offer limited utility and lead to inefficient resource allocation with minimal socio-economic advantages. Local authorities are confronted with significant bridge requests from multiple stakeholders, including local leaders, but lack a systematic approach to prioritization. This situation invites excessive political interference, often resulting in the selection of bridges that do not have adequate social or economic justification (LRBP, 2013). Political leaders have been known to use their influence at the federal level to secure bridge projects in their constituencies for political leverage, leading to delays in the preparation and endorsement of provincial transport master plans (Government of Nepal, 2022). While the Department of Roads (DOR) policy requires a systematic process involving pre-feasibility studies, stakeholder discussions, and priority-based selection, the process is centralized and politicized in practice. The National Planning Commission often makes final decisions on bridge construction, allocating budgets through the Annual Development Program list (commonly known as RED book) without clear criteria or technical feasibility. Many projects are selected based on political demands, and local divisions often have minimal input. Prefeasibility and feasibility studies are reduced to formalities and are rarely used for actual planning or budgeting purposes. Ad-hoc planning is a significant issue in bridge project implementation, and a more scientific, organized approach, prioritizing projects based on genuine need assessments and ensuring feasibility studies, should guide selection and construction (Mulmi, 2013).

Research indicates that human judgment often relies on simplifications that introduce biases, like favoring recent or familiar experiences. MCA helps reduce these biases by structuring decisions around weighted criteria to objectively rank options from most to least preferred. MCA does not assume any single option excels across all goals but enables a systematic assessment of alternatives, assigning relative weightings to criteria to handle complex information effectively. A prioritization matrix, used within MCA, ranks projects by importance, aiding departments in identifying high-priority initiatives while allowing flexibility to adjust criteria as priorities change. When criteria are preferentially independent, and uncertainty is not part of the model, a linear additive evaluation approach can be used, which combines each option's score by weighting and summing it, offering a consistent, widely applicable decision-making tool (Department of Communities and Local Government, 2009). In selecting infrastructure projects, organizations prioritize methods that balance financial returns and alignment with strategic goals. Burke (2009) describes numeric and scoring models, with the latter offering flexibility through multi-criteria evaluation. Scoring models weigh factors like market fit, environmental impact, and stakeholder needs, which purely financial models often neglect. Feasibility and investment studies, critical in assessing long-term viability, require a structured approach to minimize bias and ensure alignment with national and organizational goals (Bingham & Gibson, 2017).

Furthermore, public involvement and marketplace opportunities often shape project needs, especially in developing regions (Cooper & Kleinschmidt, 2011). Nineteen key criteria are identified by study on infrastructure project selection in Indonesia which is summarized into technical, administrative, strategic fit, risks and politics, and innovation. These criteria aim to modernize decision-making processes and support the development of a Multi-Criteria Decision-Making (MCDM) framework, such as AHP, for more systematic infrastructure selection (Hansen, Too, & Le, 2021).

Since its introduction in 1980 by Thomas Saaty, the Analytic Hierarchy Process (AHP) has aided decision-makers in setting priorities through pairwise comparisons, incorporating both subjective and objective factors. AHP also checks the consistency of evaluations, reducing bias. It is widely used for MCA matrix preparation and facilitates stakeholder input. This methodology has been applied across various transportation sectors to solve transport problems. AHP was most frequently applied to road traffic problems (27%), with rail transport (18%) and air transport (14%) following in frequency. Additionally, AHP was used for **traffic project prioritization** (18%) and **terminal location selection** (9%). Other notable applications include **public transport system selection** (5%), **sustainable transport infrastructure** (5%), and **maritime traffic** (4%) (Barić, Zagreb, 2015). In the national context of Nepal, the AHP has been applied across various sectors to support infrastructure and development prioritization. For instance, AHP has been used in ranking rural road projects (Bhandari, Shahi, Shrestha, 2014), evaluating criteria for public transport services in Kathmandu (Tiwari, Poudel, Sigdel, 2023), analyzing barriers to renewable energy development (Ghimire, Kim, 2018), and prioritizing rural electrification barriers (Adhikari, Pahari, Shrestha, 2020).

The 2017 Final Report from Nepal's Department of Roads, Bridge Branch focused on updating the Bridge Management System (BMS) database. It was prepared by Soil Test P Ltd., Aviyaan Consulting P Ltd., and Softwel Consulting P Ltd. This study aimed to review and improve the existing bridge prioritization approach, ultimately resulting in a prioritization matrix (Table 1) designed to support systematic decision-making for bridge projects across Nepal's river crossings.

Table 1: Existing new crossings prioritization matrix of DOR

S.no	Criteria	Weightage	Sub-criteria	Scores
1	Priority Policy of Government	0.25	Bridges in Link connecting regional/ district headquarter or bridges in all-weather roads or roads under the upgrading to all-weather roads program.	4
			Bridges in fair weather and track-opened roads.	2
			Bridges in a road segments where no track is opened.	0
2	Road Link Classification/Strategic importance of road	0.25	National highway bridges	4
			Feeder roads bridges	3
			Urban roads bridges	3

			Other roads bridges	1
3	Traffic Volume	0.30	0-49	0
			50-149	1
			150-299	2
			300-1000	3
			Above 1000	4
4	Population Served or bridge in a link serving major economic activity- Mineral Extraction /Hydropower/ Tourist Centers/Pilgrimage Places	0.05	Lower than 15000	0
			Between 15000-49999	1
			Between 50000 and 149999	2
			Between 150000-500000 or bridges in a segments linking industrial or activity of local significance or health posts	3
			More than 500000 or bridge in a segment linking major industry or commercial activity or hospitals or touristic/pilgrimage places	4
5	Road Closure Duration	0.15	> 3 months in a year	4
			2 - 3 months in a year	3
			1 - 2 months in a year	2
			10 days - 1 months in year	1
			< 10 hours in a year	0

The Comprehensive Bridge Manual by DoLIDAR outlines a structured process for prioritizing local road bridge projects, as shown in Table 2 and 3. Following a multi-stage screening and prioritization, a prioritized list of bridge demands is created. Based on resource availability, high-ranking projects are selected for detailed survey and design. DoLIDAR coordinates with district offices (District Development Committee (DDCs) / District Technical Offices (DTOs)) to implement these selected projects within each district.

Table 2: Existing prioritization matrix for new bridges of LRBP (central level)

Criteria	Points	Description	Scoring	Remarks
Population within Zone of Influence (ZoI)	50	ZOI: The people from area of ZOI will be travelling through the planned bridge	< 5000= 10.0 5000 - 10000= 20.0 10000 -20000=30.0 20000 - 30000=40.0 > 30000 = 50.0	Total score multiplied by 2.0 for the remote hilly districts and 1.5 for hilly districts, to balance the population disparities.
Road length that the proposed bridge will make all-weather	25	The length of road segment (between 2 defined node)	Less than 20.0 km = 5.0 20 to 30 km=10.0 30 to 40 km=15.0 40 to 50 km=15.0 more than 50.0 km = 25.0	
Location of bridge– potentials for inter district/regional linkages	25	Road segment where the bridge has been planned	Link between two major places / District HQ of two districts= 25 Link between two existing motorable	

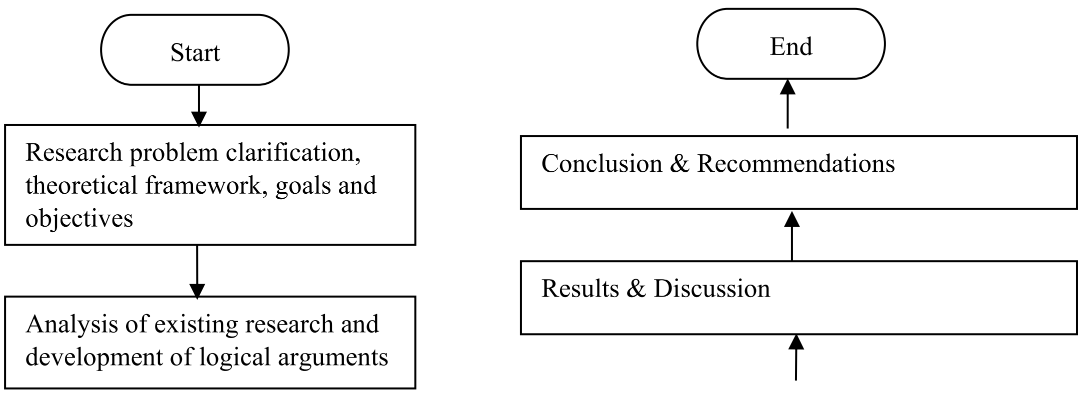
		roads: 20 Others: 15	

Table 3: Existing ranking system for new bridges of LRBP (local level)

Criteria	Points	Description	Scoring
Population within Zone of Influence (ZoI)	40	ZOI: The people from area of ZOI will be travelling through the planned bridge	Less than 1000 =10 1000 to 3000= 15 3000 to 5000= 20 5000 to 10000= 25 10000 to12000=30 12000 to 15000 =35 More than 15000 =40
Road length that the suggested bridge will make all-weather	20	Road segment length (between 2 defined nodes)	Less than 20 km=4 20 to 30 km=8 30 to 40 km=12 40 to 50 km = 16 More than 50 km = 20
Vehicles count running along the roads at both sides of river	20	The number of vehicle that will cross immediately after the bridge completion (not extrapolated, but already approaching at the banks prior to bridge construction /during dry seasons)	None= 5 Less than 5= 7.5 5 to10 = 10 10 to 20 = 15 More than 20 = 20
Distance and parts of district roads on which bridges are proposed are maintained and operable by concerned DDCs.	20	Part of the road length mentioned in the Criteria3 that will be maintained for Vehicle plying.	All length: 20 Most length:15 Around half: 10 lower than half: 5 only some: 2

3. Data Collection and Methodology

This study was conducted in 2019, during which all calibration data were gathered, and interviews with AHP participants were carried out. Primary and secondary data were collected to calibrate sub-criteria and assign weightage to criteria in the prioritization of bridge projects. Secondary data included AADT from one hundred and sixty traffic stations, DRCN data from thirteen districts in Bagmati Province, all-weather road length and bridge type/cost data, and population data for local levels in Bagmati Province. Primary data was obtained through an AHP questionnaire from twelve experts from various sectors, including the Department of Roads (DOR), DOLI, TID, and academic personnel. Data was analyzed using Klaus D. Goepel's AHP Spreadsheet Template (version 11.10.2017), applying MCA techniques to calibrate the sub-criteria and calculate criterion weights. The methodology adopted is best described in Figure 1.



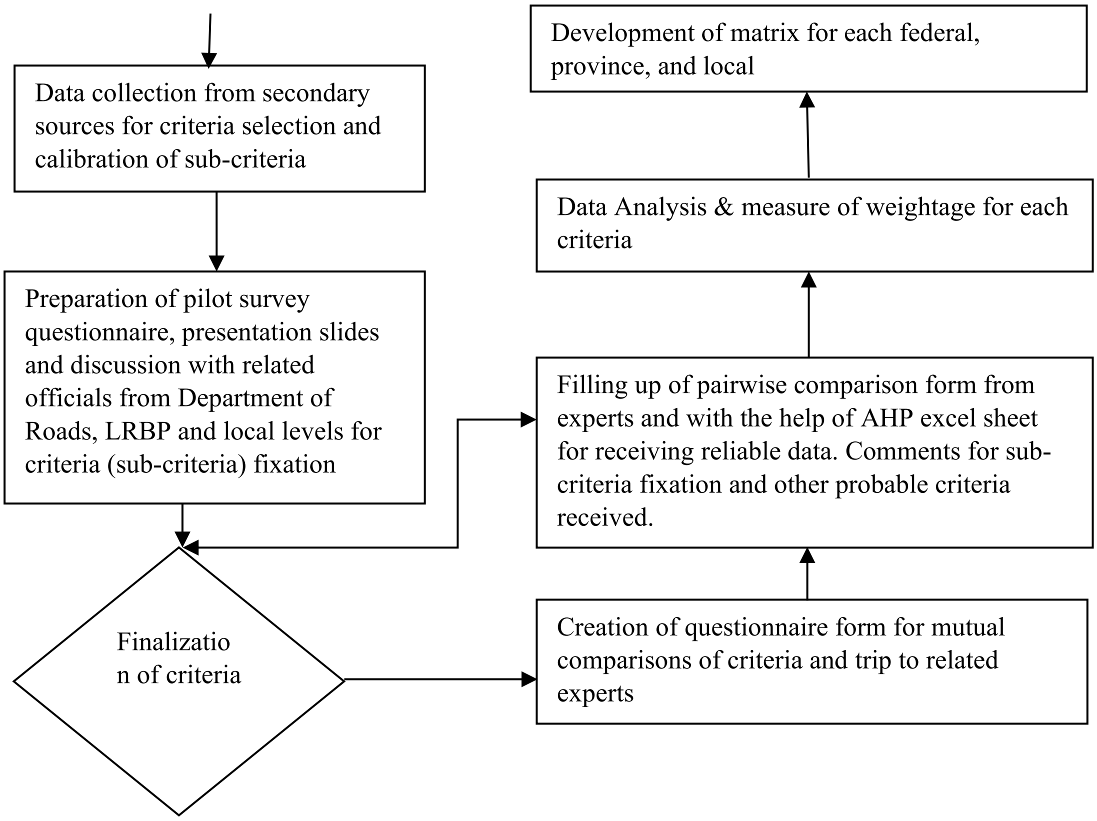


Figure 1: Overall methodological framework for the study

4. Development of Matrix

Overall matrix development stages are briefly summarized in Tables 4 and 5.

Table 4: Stages of matrix development (Part 1 of 2)

Stages	Task Performed	Description/Key findings
1.Identify deficiencies on existing matrix	Study/analysis of existing prioritization matrix and initial interview with officials from DOR & LRBP.	In DOR matrix a. The criteria weightage, sub-criteria range and scoring is provided based on judgment. b. Population related criteria was given minimal weights of 0.05 due to inadequate sub-criteria division in DOR matrix c. Effective use of Bridge Management system for project prioritization is not practiced. In LRBP matrix a. The criteria weights are based on judgments. b. Despite the presence of minimum criteria for bridges to lie in DRCN in Bridge Selection and Prioritization Criteria (BSPC), several bridges not satisfying this criterion are allocated budget and implemented.
These deficiencies highlight the key gaps that prompted the need for this study.		

2. Matrix Development basis	1. The matrix development involves creating three separate matrices for each government level, reflecting their unique goals, jurisdictions, and development policies. 2. Though these matrices have limitations, the criteria developed by DOR and LRBP, with input from field experts through rigorous studies and workshops, provide measurable and practical benchmarks. They serve as a valuable starting reference, simplifying and enhancing the matrix's overall completeness for this study. 3. The criteria selection aligns with the recent policy directives developed following the institutionalization of federalism. 4. Established national and international project prioritization practices from policy documents and academic sources are followed while keeping the criteria as streamlined as possible. 5. While some limitations exist, the sub-criteria for different criteria were calibrated based on available data from previous applications.
3. Pilot Survey	1. Based on the literature review, criteria were finalized for each government level: three for federal, five for provincial, and four for local. A pilot survey validated these criteria, including input from agencies like the Department of Roads, Bridge Branch, DOLI/LRBP, and municipal offices. However, this phase of the study is a notable limitation. 2. Still, some valuable insights emerged during initial visits to different agencies to collect responses for the pilot survey: a. Officials from the DOR supported the proposed three criteria and agreed with the exclusion of two others. They emphasized that the criteria should be kept to a minimum for bridges to be effectively executed at the central level. b. Officials from the LRBP pointed out that there are no strict rules regarding the number of criteria to include in the matrix. They acknowledged the relevance of the five criteria selected for the provincial level and stressed the need for comprehensive workshops to finalize these criteria. This process should involve coordinated efforts and input from representatives at all levels to ensure consensus. c. Participants from the local level expressed a primary concern for capacity building in bridge construction. While they found the criteria relevant, their main focus was on implementing bridge projects, highlighting the need for support in executing these initiatives effectively.

After the pilot phase, the matrices were refined to meet specific objectives at each government level. The federal matrix prioritizes bridges on crucial links under federal jurisdiction, with higher AADT and detailed project studies. The provincial matrix ranks bridges based on their importance within the provincial network, serving more vehicles, requiring lower per capita investment, and supporting socio-economic activities. The local matrix prioritizes bridges that enhance local connectivity, reduce road closures, and are maintainable by local governments.

Table 5: Stages of matrix development (Part 2 of 2)

Stages	Task Performed	Key Information/findings
4. Analytic Hierarchy Process	Pairwise comparison sheets for each selected criterion were prepared and intensity Scale used for scoring is defined.	For the federal level, 3 comparisons (3C2) were made; for the provincial level, 10 comparisons (5C2) were made; and for the local level, 6 comparisons (4C2) were made. A score of 1 means equal importance, 3 indicates moderate importance, 5 reflects strong importance, 7 shows very strong importance, and 9

		represents extreme importance. Intermediate scores of 2, 4, 6, and 8 are used for nuances between these levels.
	Twelve participants contributed to the study by providing input through the questionnaire.	The group involved in data collection included the mayor of a municipality, two senior engineers from the Department of Roads (DOR), four senior engineers from the Department of Local Infrastructure (DOLI), two professors from Institute of Engineering (IOE), Pulchowk, and various bridge experts, including designers and consultants. Data was entered immediately to ensure consistency. During data collection, participants provided various perspectives on criteria selection and bridge prioritization.

The data aggregation in the AHP process was carried out using the geometric mean method to determine the criteria weights from pairwise comparisons provided by 12 participants. While the Template was employed for full-scale calculations, a simplified example is presented here, illustrating the methodology with a federal matrix featuring 3 criteria (Road Link, Present Traffic, and Project Readiness) and pairwise comparisons from 3 participants.

Step 1: Pairwise Comparison Matrices

The pairwise comparison matrices provided by three participants are shown below:

$$\begin{bmatrix} 1 & 5 & 7 \\ 1/5 & 1 & 2 \\ 1/7 & 1/2 & 1 \end{bmatrix} \qquad \begin{bmatrix} 1 & 9 & 7 \\ 1/9 & 1 & 1 \\ 1/7 & 1 & 1 \end{bmatrix} \qquad \begin{bmatrix} 1 & 5 & 8 \\ 1/5 & 1 & 4 \\ 1/8 & 1/4 & 1 \end{bmatrix} \qquad \begin{vmatrix} \text{Road Link} \\ \text{Present Traffic} \\ \text{Project Readiness} \end{vmatrix}$$

Step 2: Consistency Check

The Consistency Index (CI) and Consistency Ratio (CR) measure the consistency of pairwise comparisons in the AHP process. The CI is derived from the principal eigenvalue, and the CR is obtained by comparing the CI to a standard Random Index (RI). The Alonso/Lamata linear fit method adjusts the CR calculation to improve reliability. The comparisons are considered acceptable if the CR is below the threshold (typically 0.1) (Goepel, 2013). Any inconsistencies were handled using the Template, ensuring the reliability of the aggregated results. After performing the consistency check, the Consistency Ratios (CR) for the three pairwise comparison matrices were calculated as follows: CR for Participant 1 = 0.01, CR for Participant 2 = 0.01, and CR for Participant 3 = 0.10. All CR values are below the threshold of 0.1, ensuring the reliability of the judgments.

Step 3: Aggregation of Judgments

The pairwise comparison matrices were aggregated using the row geometric mean method (RGMM).

$$GM_{ij} = \sqrt[3]{P1_{ij} * P2_{ij} * P3_{ij}}$$

Where:

GM_{ij}: Row Geometric mean of the pairwise comparison values for criterion i and j.

$P1_{ij}$, P2ij, P3ij: Pairwise comparison values provided by Participant 1, Participant 2, and Participant 3, respectively.

The aggregated matrix is as follows.

$$\begin{bmatrix} 1 & 6.08 & 7.32 \\ 0.16 & 1 & 2 \\ 0.14 & 0.50 & 1 \end{bmatrix}$$

Step 4: Normalized Weights

The row geometric mean values were normalized to calculate the criteria weights. Sample criteria weights are presented in Table 6.

Table 6: Sample criteria weights after aggregation

Criterion	Weight
Road Link Classification	0.76
Present Traffic Volume	0.15
Project Readiness	0.09

Step 5: Consensus

The AHP consensus is determined in the summary sheet by analyzing the row geometric mean method (RGMM) results from all inputs using Shannon alpha and beta entropy. The consensus indicator ranges from 0% (indicating no agreement among decision-makers) to 100% (signifying complete agreement among decision-makers). (Goepel, 2013)

5. Discussion on Criteria Selection

Eight criteria were selected in total. Tables 7 and 8 present key details in tabulated form.

Table 7: Descriptions about selected criteria/sub-criteria (Part 1 of 2)

S.no.	Criteria	Scope	Description/Sub criteria calibration
1	Strategic Importance of Road/Government Priority Policy	Federal, Province, Local	• As per the Constitution and latest policy documents
2	Traffic Volume (Average Annual Daily Traffic (AADT)/Vehicle per day (VPD))	Federal	• Traffic data from 2015/16 sourced from the DOR Road Diary, average of ten highest AADT (8849.5 PCU) and average of ten lowest AADT (127.2 PCU) are assigned score 4 & 0 respectively. Intermediate scores calculated using a linear function based on these values.
		Province	• DRCN requiring bridges and their respective VPD recorded from District Transport Master Plan of 13 districts of Bagmati Province. VPD data inflated from 2015 to 2019 using vehicle growth rate of 8.36% per year. Highest VPD (54) and lowest VPD (0) are assigned score 4 & 0 respectively. Intermediate scores calculated using a linear function based on these values.
		Local	• Same as province is adopted for local level due to unavailability of Village Road Core Network (VRCN) data.
3	Project Readiness	Federal	• The DOR revealed over 2000 bridges with detailed project reports (DPR) ready but delayed due to shifting political priorities. • This criterion received strong support during federal matrix slides presentation at DOR, Bridge Branch. • A DOR review by Mulmi recommended selecting bridge projects based on completed feasibility and detailed surveys. • The Bagmati Province budget speech emphasized prioritizing projects with completed feasibility studies and technical

			designs. • International practices, such as Cambria County's 25-year Transportation Plan (2015-2040) and preliminary study for Public Private Partnership (PPP) Projects in the Philippines, use project readiness to prioritize projects.

Table 8: Descriptions about selected criteria/sub-criteria (Part 2 of 2)

S.no.	Criteria	Scope	Description/Sub criteria calibration
4	Access to Socio-Economic Activities	Province	• The provincial government is tasked with enhancing local access and network connectivity, while the federal focus is more on national issues. Thus, the proposed criterion "Access to Socio-Economic Activities" is pertinent at the provincial level. This proposed scoring system is informed by expert suggestions and emphasizes the importance of offering access to crucial socio-economic activities through bridge construction. • A consultant involved in preparing DOR matrix noted that, despite a low weight of 0.05 in the DOR matrix, the "population served" criterion was crafted based on regional demographics (Himalayan, hilly, and Terai regions). Though imprecise, it remains crucial for evaluating bridge impact. • The DOR matrix assigns a score of 4 to bridges serving major industries, hospitals, or tourist sites and 3 to those serving local significance or health posts. A more precise definition differentiates between "major" and "local" industries.
5	All Weather Road Length	Province	• Data of 29 bridges constructed in Bagmati Province is used. • The maximum all-weather road length recorded as 30 km, and the minimum 3 km are assigned scores 4 and 0, respectively. Intermediate scores calculated using a linear function based on these values.
6	Per Capita Investment	Province	• Calculated by dividing bridge costs by the population they serve. Helps prioritize bridges that benefit larger populations with lower investment. • Data of 98 bridges in Bagmati Province is used. Samari Khola Bridge with highest per capita cost (Rs. 7054.34) and Gangatte Khola Bridge the lowest (Rs. 123.67) are assigned score 0 & 4 respectively. Intermediate scores calculated using a linear function based on these values. • While the study used municipal population data for selection, the concept of a ZOI would be more accurate if data were available

7	Road Closure Duration	Local	• This criterion, used in the DOR matrix, assigns a weight of 0.15 to assess the impact of road closures due to the absence of bridges. • It is noted that local levels will likely receive shorter bridges, particularly over rivers with lower discharges and sporadic flash floods, while longer bridges are expected at the provincial or federal levels. • The sub-criteria from the DOR matrix, which define road closure durations for perennial rivers with significant discharge, may need revision to better reflect local contexts. However, due to time constraints, the original sub-criteria from the DOR matrix have been retained for this study.
8	Roads that can be maintained and operated by local level.	Local	• Without adequate maintenance capabilities at the local level, the effectiveness of all-weather roads is diminished. Local maintenance capacity can be influenced by factors such as proximity to headquarters, the significance of the road, and the local government's financial resources. • The sub-criteria mirror those used in the LRBP matrix, focusing on the extent of road length that can be maintained effectively.

The Population and Road Closure Duration criteria were omitted from the federal-level bridge prioritization matrix for the following reasons:

1. Federal Jurisdiction Focus: The federal level focuses on national connectivity, such as north-south and east-west highways, and strategic connections between capitals. Since these bridges serve large-scale national objectives, the population a bridge serves is less relevant. This criterion will be more suitable at the provincial level, where local population impacts are more significant.
2. Population Criterion Weight: Previously, the population was assigned a low weight of 0.05, and its sub-criteria were imperfectly calibrated, making it less significant at the federal level.
3. Road Closure Duration: For federal roads, the origin and destination are well-defined, and all bridges are equally important in maintaining link functionality. This criterion is more relevant at the local level and will be included there.

All stakeholders agree that the selected criteria for bridge selection are not exhaustive, but data limitations make refining sub-criteria infeasible. Key suggestions include:

1. Federal officials propose incorporating political inputs with a small weight for forced prioritization.
2. DOR personnel find the MCA matrix useful but suggest separate funding for major highways.
3. Experts emphasized traffic volume, bridge proximity, structural safety, and road standards as potential additional criteria.

These discussions highlight the importance of stakeholder input for balanced, consensus-driven decision-making and suggest future research on refining criteria.

In validating the scores for the bridges in Bagmati Province, the ranking was derived using the federal-level matrix, which was the only level for which complete data were available. However, due to the unavailability of data for the provincial and local levels, it was not possible to apply the respective matrices or conduct additional score validation. Future studies could aim to address these gaps by gathering data at all levels and incorporating expert or stakeholder reviews for a more robust validation of the prioritization framework.

Table 9: Bridge prioritization ranking and scores

Rank	Bridge details	Criterion weights			Total score (A*0.581+ B*0.284+C*0.135)
		Road link (A)	Present traffic (B)	Project readiness (C)	

1	Sansare bridge, Mahendra Highway Ch.392+280	4	1	0	2.61
1	Mamti Khola Bridge, BP Highway	4	1	0	2.61
2	Trisuli River Bridge, Pasang Lamhu Road	3	1	0	2.03
2	Khani Khola Bridge, Tamakoshi Manthali Road	3	1	0	2.03
3	Karmanasa Bridge, Thimi Tikathali Imadol Road	0	3	0	0.85
3	Ghatte River Bridge, Sallaghari-Lubhu Road	0	3	0	0.85
3	Sankheshwa Bridge, Gwarko Panauti Road, Kavre	0	3	0	0.85
3	Hanumante Khola Bridge, Kaushaltar-Balkot-Sirutar Road	0	3	0	0.85
4	Martal River Bridge, Dumre Khadi, Chepang Marga	0	0	2	0.27
4	Gongar River Bridge, Thakaltar, Chepang Marga	0	0	2	0.27

The bridges in Table 9 are samples taken from 17 bridges planned for implementation by the DOR Bridge Branch in Bagmati Province in the fiscal year 2019/20. The ranking table assigns higher priority to bridges on national highways and lower priority to urban roads and roads like Chepang Marga, reflecting each level's distinct needs and jurisdictions. Here, we can also deduce that the ranking reflects the Department of Roads' prioritization of national highways, while heavy traffic handling urban roads is ranked lower. For bridges with the same score, the concept of forceful prioritization, as indicated earlier, may be utilized to differentiate their ranking.

6. Results

At the federal level, the highest weight (58.1%) was assigned to strategic importance, followed by AADT (28.4%) and project readiness (13.5%). The consensus among participants was 62.4%, indicating a strong agreement. The Principal Eigenvalue was 3.009, with a Mean Random Error (MRE) of 9.4%, a Geometric Consistency Index (GCI) of 0.03, Psi of 0%, and a Consistency Ratio (CR) of 0.9%. The final derived matrix for federal level is shown in Table 10.

Table 10: Federal level matrix

S.no	Criteria	Weight	Sub-criteria	Scores
1	Strategic Importance of Road/Government Priority Policy	0.581	National Highway bridges/ Bridges in links joining east-west highways to province capital's & federal capital/north south highways joining cross-borders	4
			Bridges in links joining federal/ province capital to Pushpalal highway & Links joining national highway to projects of national pride/ link connecting national road network to district headquarters.	3
			Trade links connecting federal/ province capital from east-west highway to north-south highways	2

			Bridges on roads handed over on province request	1
			Bridges on other roads	0
2	Present Traffic Volume (AADT)	0.284	Above 7000	4
			4500-7000	3
			2500-4499	2
			150-2499	1
			less than 150	0
3	Project readiness Level	0.135	Detailed survey/design/IEE running or finalized	4
			Detailed Feasibility Study finalized / running/committed	3
			Pre-feasibility Study running/ committed	2
			Conceptual stage	0

At the provincial level, strategic importance remained the most significant criterion (34.3%), followed by access to socio-economic activities (22.9%), all-weather road length (16.6%), and present traffic volume (14.9%), while per capita investment ranked lowest (11.3%). The participant consensus was 55.6%. The Principal Eigenvalue was 5.099, with MRE at 22.5%, GCI at 0.08, Psi at 20%, and CR at 2.2%. The final derived matrix for province level is shown in Table 11.

Table 11: Province level matrix

S.no	Criteria	Weight	Sub-criteria	Scores
1	Strategic Importance of Road/Government Priority Policy	0.343	Road segments joining National Highway/Feeder road/Province highway to local level headquarters.	4
			Road segments joining district Head Quarter (HQ) and local level HQ	3
			Road segments joining two or more than two local level HQ	2
			Road excluded from above three sub-criteria and executed by DOLIDAR previously.	1
			Other roads	0
2	Access to socio-economic activities	0.229	Connecting important tourism /cultural / hydropower sites or passage to at least three small-scale industries (agriculture, livestock, production -related)/ Health centers/education centers.	4
			Passage to two small-scale industries (agriculture, livestock, production-related)/ Health centers/education centers.	3
			Passage to single small-scale industry (agriculture, livestock, production- related)/ Health Center/ education center.	2
			No activities in all weathered road sections	0
3	All weathered road length	0.166	more than 23 km	4
			17-23 Km	3
			10-17 Km	2
			3-10 Km	1

			Less than 3 km	0
4	Present Traffic Volume (VPD)	0.149	More than 40	4
			31-40	3
			16-30	2
			1-15	1
			None	
5	Per Capita Investment(Rupees)	0.113	0-149	4
			149-2000	3
			2000-3500	2
			3500-5500	1
			Above 5500	0

At the local level, road closure duration was given the highest weight (34%), followed by strategic importance (27.1%), present traffic volume (21.4%), and all-weather road length (17.5%). The participant consensus was 53.9%. The Principal Eigenvalue was 4.044, with MRE at 17.2%, GCI at 0.06, Psi at 25%, and CR at 1.6%.

The final derived matrix for local level is shown in Table 12.

Table 12: Local level matrix

S.no	Criteria	Weight	Sub-criteria	Scores
1	Road closure Duration	0.340	> 3 months in a year	4
			2 - 3 months in a year	3
			1 - 2 months in a year	2
			10 days - 1 month in a year	1
			< 10 days in a month.	0
2	Strategic Importance of Road/ Government Priority Policy	0.271	Road segment joining local level HQ/main settlements with National Highway/Feeder road/Province highway	4
			Road segment joining local level HQ and major settlements / cultural / economic / tourism destinations.	3
			Road segment joining two or more main settlements.	2
			Other roads	0
3	Present Traffic Volume (VPD)	0.214	more than 40	4
			31-40	3
			16-30 Km	2
			1-15 Km	1
			None	0
4	Roads that can be maintained and operated at local level.	0.175	Whole length	4
			Most length	3
			about half	2
			lower than half	1

only some	0

7. Discussion

MCA used in this study allows flexibility in adjusting the criteria based on stakeholder input, expert opinions, and the matrix's intended application. This adaptability is a key strength of MCA, enabling it to reflect the priorities of various levels of government. For example, the weightings given to factors like traffic volume and strategic importance vary across levels. At the federal level, strategic importance carries the most weight, reflecting national priorities, while at the provincial level, this is balanced with socio-economic factors. The local level places greater emphasis on road closure duration, underscoring the operational challenges faced at that tier. These differences illustrate how MCA accommodates the unique priorities and challenges of each level of governance. However, during the study, challenges with AHP and the tools used for analysis became apparent. Participants needed additional guidance to understand the software and its reflection of their inputs in the final results.

8. Conclusion

The research employs a holistic approach to bridge prioritization, which is applicable across various government levels. The AHP comparisons used remain valid, and the study aims to spark critical thinking and encourage feedback from transportation experts. This will help develop a more effective matrix for prioritizing bridges. Additionally, aligning the bridge selection policy with these matrices can help clarify and strengthen the specific goals of each level's transportation network. Ultimately, the study strives to reduce political influence in the bridge selection process and promote more objective decision-making in Nepal.

9. References

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