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Road Maintenance Practices in Nepal: A Case Study of Malekhu – Mugling Road Section

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Abstract

Road degradation is a major issue in Nepal due to main focus only on backlog maintenance and upgradation which evidently is an unsuccessful maintenance investment strategy worldwide. Considering global success of PBMC in time-cost-quality spectrum, it has been implemented in Nepal since 2003 but without success. Thus, ADB in 2016 revised PBM specifications and re-executed it, whose performance potential must be accessed with respect to current SMDP practice. The current study analyzes and compares effectiveness of SMDP and PBMC in terms of cost and quality for Malekhu- Mugling road section, and suggests a suitable maintenance practice in the current scenario of Nepal. This study reveals that strengthening SMDP practice shall be focused on before releasing a long term PBMC. The study concludes that the most suitable practice in terms of cost quality optimization is a strengthened SMDP as per PBMC standard whereby length worker perform PBMC standard routine, pavement and intervention based repairs due to their reliability during emergency. Then, one year contract shall be released incorporating two recurrent (prior and post monsoon) and a specific contract where contractors essentially follow performance based maintenance of roadside structures, traffic safety, pavement defects if any, and any emergency maintenance during monsoon. It is recommended that PBMC model shall be developed gradually from one year contract to multiyear contracts since there may be high chances of claims and conflicts in four year long PBMC.

Keywords: *SMDP, PBMC, Performance Based Maintenance, Malekhu- Mugling road section, ADB*

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1. Introduction

Roads deterioration occurs mainly due to water and traffic. The road deteriorates slowly in the 1st phase with minor tears. Deterioration accelerates further exponentially in the 2nd phase if unattended as the stagnant water further damages the road structures. The road completely becomes non-motorable at 3rd phase. Road maintenance costs too increase exponentially with each phase [1].

The maintenance activities of SRN in Nepal are being implemented through 33 road divisions under the DoR Maintenance Branch. Planned maintenance activities initiated with the help of SMDP are used for planning annual maintenance programs whereby each division prepares the ARMP consisting of maintenance programs under different maintenance budget heads like routine, recurrent, specific, periodic, and low scope emergency maintenance, that is later integrated to develop the IARMP by DoR. The contracts for recurrent, specific, periodic and emergency maintenance are contracted on the basis of item rate payment, whereas the length workers responsible for routine maintenance under the supervision of DROs are paid on daily wage basis at monthend [2] (Source: Department of Roads).

PBMC is an agreement between a government agency (DoR) and a private contractor whereby in exchange for a fixed monthly lump sum fee bidded in kilometer-months, contractor maintains the road for minor maintenances (expressed as threshold material quantities per rectification event) to meet defined performance standards in the performance specifications provided in bidding document. Specified penalties are imposed in monthly lump sum amount if not maintained as per the performance standards [3]. The main benefit of PBMC over traditional maintenance practices is that it provides road agencies benefits of improved road conditions with limited investment available through incentives or flexibility to the contractor for use of innovative maintenance approaches [4]. Other benefits are on time intervention of road defects inducing potential cost savings in future [5], and heavy traffic road performance is significantly guaranteed during multiyear contract [6].

Significant cost savings of PBMC have been recognized in past projects implemented on sections of Mahendra Highway. However, projects failed because the level of service effectiveness was not achieved for the given budget since the performance indicators at that time were not feasible in Nepalese environment [3]. ADB then redeveloped the specifications based on past experiences and reimplemented in Narayanghat- Butwal section [7], which could perform the other way. Cost and quality comparison between existing SMDP and potential PBMC can suggest either better ways of strengthening SMDP or implementing PBMC with modifications if necessary. Thus, the study can further provides the insight to which options among the two shall be beneficial in terms of cost quality optimization for Malekhu-Muglin section, as well as in the wide context of Nepal.

2. Literature Review

2.1 Life cycle cost Analysis (LCCA)

LCCA is an analysis technique based on the principles of economic analysis to evaluate the overall long term cost efficiency between competing alternative investment options, and to take investment decisions consequently. The main objective of LCCA in the study is to find the main alternative maintenance strategy that meets the performance requirements at lowest life cycle cost thus identify the best value for investment expenditures [8].

The following are the steps in conducting LCCA of PBMC and taking investment decisions between PBMC and SMDP [8]:

Step 1. Determine analysis/ performance periods and activity timing of PBMC.

Step 2. Estimate relevant costs required to meet the performance requirements (MSLs and OSLs).

Step 3. Develop expenditure stream diagrams for PBMC i.e. graphical representations of expenditures over

time that depicts extent and timing of expenditures.

Step 4. Compute Net Present Value (NPV).

Step 5. Compute Uniform Equivalent Annual Cost (UEAC).

Step 6. Compare UEAC of PBMC with annual cost of SMDP for a particular fiscal year.

A. Net Present Value (NPV) calculation: NPV is the economic indicator in choice of alternate investments. The basic NPV formula for discounting discrete future amounts of PBMC at various points in time back to some base year is:

Equation 1

$$NPV_{PBMC} = \text{Total Monthly Lump sum}_{12n} \times \frac{(1+i)^{12n}-1)}{i(1+i)^{12n}}$$

where,

i = discount rate for Future Costs

n = no. of years in which the expenditure incurred during the PBMC period

B. Uniform Equivalent Annual Cost (UEAC) calculation: UEAC represents the NPV of all discounted costs of an alternative as if they occur uniformly annually throughout the analysis period. It is specifically useful indicator when budgets for investment are established on annual basis. NPV is determined first and the following formula is used to convert to UEAC:

Equation 2

$$UEAC_{PBMC} = NPV_{PBMC} \times \frac{i(1+i)^{n}}{i(1+i)^{n}-1}$$

2.2 Key Informant Interviews

Key informant interviews are in-depth qualitative interviews with people who have knowledge of the research problem designed to provide insight into the essence of the problems, and proposals for solutions. It can be face-to - face interview or by telephone. There is no clear answer to the problem of 'how many' and that the sample size is contingent on a variety of factors. Qualitative samples are purposive samples, selected by virtue of their capacity to provide rich information, relevant to the core of the investigation [9]. The more useable data are collected from each person, the fewer participants are needed [10]. Researchers are suggested to take into account the parameters such as scope of study, nature of topic (i.e. complexity, accessibility), data quality and research design.

2.3 Previous works

Cost efficiency analysis of completed PBMC projects in Nepal has been accessed where comparison of the maintenance cost based on the SMDP practice and PBM contract for 5 years has been carried out to access the cost savings [3]. Total annual maintenance costs of SMDP i.e. the sum of the routine maintenance, routine bridge maintenance and the recurrent maintenance cost was calculated whereas for PBMC, overall maintenance cost as per bid amount for overall project period was taken. Contractor bidding behavior average discount of 40% is applied to the total maintenance cost based on SMD. The cost comparison showed that PBM Contracts are more cost saving than the SMD Maintenance practices. The minimum cost saving of 0.82% is observed in Phuljor-Pathalaiya contract and the highest cost saving of 54.08% of maintenance cost is observed in Chaurahawa – Phuljor contract. The cost saving from 31.6% to 42.05% have been observed in the other projects. This does not considered the saving of overhead of each year procurement which has to be done in the case of SMD Process.

Quality analysis of completed maintenance works of performance based maintenance component on those road sections under Road Network Development Project (RNDP) implemented by ADB showed following results [11]:

- The RNDP contracts were affected by civil unrest at that time. Maintenance works were delayed so that the duration of PBM activities had to be reduced.
- The measurement of PCUM works was insufficient to repair all the pavement damage on this contract. Contractor resealed all the highway, including the areas where pavement was showing signs of distress and had not been repaired under PCUM. Those areas were not expected to survive PBM period without significant deterioration.
- Contractors were encouraged to take over the DoR length workers for routine works under PBMC. The work of length workers was significant in all five contracts under RNDP.
- The major distresses in all sections under RNDP consisted of longitudinal cracks due embankment settlement rather than pavement failure. Such cracks were expected to open up and contribute to pothole formation as the reseal aged.
- The Lamki-Attariya road section of Kohalpur-Gaddachauki road project suffered major damage during 2008 monsoon, with embankment being overtopped and eroded in a number of places. Work was completed as per Emergency Works section of Bill of Quantities. The quantities included for Emergency Works were insufficient to complete the repairs. At the time of inspection, two months after the end of monsoon, the damaged areas had been marked and were continuing to carry traffic but the damage had reduced the width of the road which had restricted the free flow of traffic. Attariya-Gaddachawki section also suffered similar damage and reduced road width was reported to have caused at least one significant accident.

Quality analysis SMDP work performance in current context shows following results:

- Inadequate budget allocation by RBN for different maintenance budget heads has become serious issue. This shall induce the problem of backlog maintenance in future (Source: Final ARMP Report)
- Recurrent maintenance could so far not be implemented in all SMDPs in the standardized cyclic manner due to untimely budget release. As a result road deteriorate at an undesirable pace [3].
- The levels of routine and recurrent road maintenance activities are not sufficient to prevent longer term road deterioration. The reason for this is that in case of gravel surfaced roads loss of gravel will necessitate replacement at periodic intervals; in the case of bitumen surfaced roads oxidation of the bitumen will necessitate periodic resealing to avoid excessive potholing [3].
- Length Worker System was introduced in Nepal through the SMDP, based on the experiences of Lamosangu-Jiri road built and maintained by Swiss assistance. It has not only improved the quality of road maintenance significantly but moreover been supporting effectively the livelihood of the workers since then and is a positive aspect of SMDP [3].

3. Study Area

The study area is taken as Malekhu to Mugling road section of chainage 43+542 to 82+403.51 km a part of Prithvi Highway under supervision of Bharatpur Road Division Office. It is one of the main sections of NNM road, 94.7 km on the pivotal north-south trade corridor connecting Kathmandu and Birgunj and other Terai Regions on the way to Indian border. NNM road is also one of the key roads connecting Kathmandu to other major cities such as Pokhara (a major tourist destination), and Narayanghat (a major link to Mahendra Highway from Kathmandu) [12].

The existing two lane NNM road will be upgraded as per Asian Highway Standards from current average pavement width of 7 metre to 9 metre on average and 1 metre sealed shoulders each under SRCTIP project of ADB [13]. It will be contracted for upgrading works of 2.5 years and maintained under PBMC for 4 years after the finishing of upgrading period and 1 year defect liability period. PBMC model which had failed previously in maintaining SRN sections of Mahendra Highway is again to be implemented in this NNM section of 38.861 km of Prithvi Highway.

4. Data collection and Analysis

Annual minor maintenance costs before Malekhu- Mugling road upgradation and quality aspects comparison is done of SMDP and PBMC practice to find the most suitable maintenance practice for the section at first. The annual costs of SMDP for the research section is collected from Bharatpur divisional ARMP software data [2] for routine minor maintenance, and from pre-tender estimates for recurrent minor maintenance. The annual costs of both practices are taken of only minor maintenance of research section for current pre-upgradation scenario thus are equivalent and comparable.

Table 1: Total Administrative costs of SMDP , PBMC equivalent for Malekhu – Mugling Section

S.N	Maintenance activity	Smdp maintenance cost as of 2076/77 fy rates, pbmc equivalent (nrs.)
1	Routine maintenance	45,17,890.01
2	Recurrent maintenance	85,03,715.00
	Total :	**1,30,21,605.00**

The annual costs of PBMC for the research section is extracted from the life cycle cost analysis of the total sum of monthly lumpsum estimates to be paid to the contractor as well as supervision consultant over four year maintenance phase contract period. The quantity estimate for monthly lump sum payment to contractor is done as per the most recent PBM specification clauses of Mugling-Pokhara Highway Improvement Project and estimates of Narayanghat-Butwal Road Improvement Project are accessed for the rates. The monthly lumpsum for contractor is estimated as Rs. 27, 583 per kilometer-month. and for supervision consultant is estimated Rs. 3,43, 250 per month. *Equation 1* is used to convert uniformly distributed total monthly payment of Rs. 14,42,728 for 4 years life cycle to NPV of Rs. 5,73,17,258. The number of monthly intervals (n) is taken 48, and monthly growth rate ($i_{monthly}$) is taken 0.833%. NPV then is converted to UEAC using *Equation 2* whose value is Rs. 1,80,81,921. The number of yearly intervals (n) is taken 4, and yearly growth rate (i_{yearly}) is taken 10% for UEAC calculation. This annual life cycle PBMC cost is compared with the SMDP annual cost in Table1.

Qualitative analysis of SMDP and PBMC with respect to performed work quality extracted from pre-tender estimates of recurrent maintenance is done and compared which is given in the table below.

Table 2: Performed work quality analysis and comparison of SMDP and PBMC:

Repairs	SMDP	PBMC
A. Pothole repair	17%-22% costs are spent only on deep patch due to untimely repair expansion as per pre-tender recurrent estimates.	Costs are saved as repaired within 48 hours, a defect rectification period fixed so as to avoid expansion. Shallow patch is enough.
	Routine repair is required due to safety issues, and further expansion that increases annual defect quantity and budget .	Routine repair within 48 hours, savings in annual pothole repair budget and vehicle operating costs, and increased traffic safety.
	Current length workers are not trained for pothole repairs.	Trained Routine Maintenance Units (RMU) are productive than length workers in meeting PBMC standard routine works and pothole repairs too.

B. Gabion and retaining wall repairs (structural repairs)	Minor works are attended during 2 recurrent contracts and major during 1 specific contract annually.	Attended within in a month right after identification during monthly inspection.
	Recurrent contract procedures required frequently for minor maintenance.	Minor maintenance flexible since threshold quantity specified and contractor risk is shared.
	Minor gullies are handled by length workers. 6 months is still a long time for major gullies, may induce landslide.	Maximum cross sectional dimension of erosion gullies are specified thus saves future emergency costs through early rectification.
C.Traffic safety works	a) Traffic signs installation and painting are done twice a year in SMDP. Defects may arise early on for such sensitive issue.	a) Traffic safety defects are accessed daily and rectified monthly.
	b) b) Payment is item rate based so no risk to contractor.	b) No threshold quantity in PBMC has been specified for traffic safety devices and expensive thermoplastic paints.

During above cost and performed work quality analysis, it could be clearly seen that a time based intervention for maintenance is lacking in SMDP which has been carefully considered in PBMC in the form of defect rectification period. Quality of works done in PBMC is also high since service levels are clearly specified, which is missing in SMDP.

Also during cost estimate of PBMC, it is highlighted that routine maintenance unit have a great role to play in timely maintenance in PBMC since scope of routine activities is high than current SMDP practice and also some portion of recurrent maintenance of current practice are taken as routine in PBMC (pothole repairs, etc). If current length workers are to be added, trained and used for maintenance of increased scope of routine activities based on PBMC standards and made to perform pothole repairs as per performance levels and penalty imposed if not maintained, significant costs can be saved in future recurrent maintenances. Also, from the literature 2.3, contractors have widely adopted the length workers during their contract period. So, strengthening of SMDP as per PBMC standards needs to be studied since it may result to be more effective practice and may reduce the need of costly PBMC.

A qualitative comparison is performed between different significant aspects of SMDP and PBMC maintenance practice identified during research which is provided in the table below.

Table 3: Qualitative Comparison of significant aspects of SMDP and PBMC

Quality issue	PBMC	SMDP
Drain repairs	Repaired monthly and cleared daily (monthly in dry seasons).	Cleared daily. Repaired yearly under specific maintenance but is a crucial part.
Tendering costs	A 4 year contract is performed at a time. No frequent tendering is required since minor works paid monthly lumpsum and major need only work order.	Recurrent contracts 2-3 times and specific contract one time a year.
Cost savings in future	Saved from timely maintenance of potholes, structures, etc which avoids exponential propagation of defects.	Saved if recurrent maintenances are performed on intervention basis along with routine maintenance in parallel.
Road maintenance data	Record shall be updated in government system every 3 months. Contractor's daily report is also available.	Road maintenance record is updated in government system every 2 years. Record of routine maintenances is not available

Key informant interview of professionals having good experience in PBMC and SMDP have been taken to validate the results of cost and quality aspects of respective maintenance practices and recommendations for

the most suitable maintenance practice for Nepal. As per the literature 2.2, qualitative samples are purposive samples so that the more richer the information from each person, the fewer participants are needed for interviews. So, sample of five professionals were taken for key informant interview, analysis of which gave the following outcomes:

- Cost reductions from PBMC specification-wise estimate: The management service obligations and respective costs for Performance Monitoring unit and the assets to be maintained by RMUs has been removed because inclusion of such costs is only feasible when a road stretch is contracted of 200km and more, The monthly structural inspection of to be reduced to tri-semester inspection since monthly inspection would be too early. Communications Systems may be maintained by contractors as they find convenient and contractor obligtions.
- Pothole repairs: Timely maintenance reduces both deep patch costs and annual defect costs.
- Structural inspections: Required before and after monsoon for slope protection structures. Even during monsoon for drains.
- Drains: Drains are to be checked and repaired for any cracks caused due to vehicle parking on road sides. During monsoon emergency repairs of structures may occur and routine maintenances are required closely.
- Traffic safety: Current trend of traffic sign painting is enough. Installation to be intervention based. Thermoplastic paints are to be reserved for several years by avoiding sand grit otherwise to be repainted in 6 months. Traffic safety works are to be kept under emergency maintenance in PBMC.
- Tendering costs: High chances of saving but exactly cannot be said as bid evaluation may get complex for PBMC.
- Road management database: Must be updated as per defect items and their frequency of occurence to avoid forecasting.
- SMDP strengthening is possible if length workers are strengthened for PBMC routine maintenance standards. They shall be supported as they are very reliable during emergency than contractors who have denied to perform in past PBMCs, and also have implemented fraudulent practices during SMDP pothole, structural repairs. Also, contractors were not interested in a process based routine work where they had to be standby with equipments even without or low works. However, long term issue of old length workers s shed off must be solved before.
- Also, a single annual contract release would be effective that incorporates all current cyclic contracts. Flexibility needs to be provided on annual quantity variations for minimizing contractor risks. A negative side exists that if contractors fail to work properly, backlog maintenances shall increase exponentially.

5. Findings and Discussion

Table 4: Annual PBMC and SMDP budgets

Annual SMDP budget, PBMC equivalent	NRs. 1,30,21,605.00
PBMC budget, pre- road upgradation (SMDP equivalent)	NRs. 1,80,81,921.00

Annual PBMC Life cycle costs is 1.389 times greater than the annual SMDP maintenance budget as per the result in Table 4. This contradicts from the results of literature 2.3, where cost savings are recognized in PBMC [3] which is because contractor's bid amount has been taken for the analysis of PBMC expenditure in that study which is usually low than government estimates. Also, front loading behavior in the bid amount for improvement works of past PBMCs was significant in contractors than PBM works which showed significant cost savings for PBM works. But for this study, PBMC expenditure from the viewpoint of government's

administrative costs has been taken so, PBMC budget has resulted to be higher than that of SMDP budget.

From the observation of analysis of quality aspects of performed works, PBMC is appropriate in terms of work quality due to on time intervention and performance levels, and is costly due to its management service obligations. However in PBMC, a technical defect of non allocation of threshold quantity for significant materials shall be rectified.

After the intended removal of management service obligations on contractors for Malekhu- Mugling road project because of short road stretch as per the key informant interview of professionals, the PBMC annual costs have been reduced by 29% with respect to SMDP annual costs. Even after such significant cost reduction on PBMC, departmental length workers have been more reliable during emergency issues than contractors. As per literature 2.3, two sections of Kohalpur-Gaddachauki project showed unsatisfactory performances where the emergency work quantities were not enough as per bill of quantities and road width were reduced as a result causing further accidents. Past PBMCs failed because contractors refused or failed to perform emergency work at times as per the professionals. Fraudulent practices still exist in pothole and structural repairs in SMDP contracts. Also, as per past experiences of defects occurrence, except for pavement defects, thermoplastic paints, and some intervention based works, other defects are found to be done in right time in current practice as per the key informant interview. So, before releasing a long term contract, strengthening SMDP practice shall be focused on, and can be done in following ways:

a) strengthening length workers for PBMC standard routine works, any pavement defects that have high propagation intensity due to traffic, and all intervention based maintenances possible as per PBMC standard after solving the old length workers shed off issues, and

b) one year contract package release to a single contractor with a view of reducing tendering costs shall be released on the contractual terms of working like a current cyclic basis and paid under item rate basis, keeping under consideration the following factors:

- The defects to be repaired as per PBMC within a month rather than like current three months. Immediate action required for emergency maintenances.
- Obligation to perform slope structural inspection before and after monsoon and maintenance within a month. Constant monitoring for any emergency structural failures during monsoon and taking immediate action. Drains to be inspected before, during and after monsoon for structure repairs.
- Road management database to be provided to government as per the road defect items and their frequency of occurrence so that it doesn't have to be forecasted.
- Strict supervision, flexibility on annual quantity variations of defect and strong contract documents for strict punishment if failed to work are a must.

6. Conclusion and Recommendation

A maintenance practice that is compensation between SMDP and PBMC in terms of cost quality optimization is appropriate. SMDP shall be strengthened as per PBMC standard, strengthening of length workers for PBMC standard routine, pavement repair and intervention based maintenance works. One year contract is to be released for remaining works to be done as per current cyclic basis prior and post monsoon including one specific works per year, paid on item rates but as per the performance levels of PBMC, instead of implementing a four year long PBMC where risks are high. It is recommended that PBMC model be developed gradually from one year contract to multiyear contracts since there may be high chances of claims and conflicts in four year long contract.

Conflict of interest

"Not declared by the author(s)".

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