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Enhancing Urban Roads Maintenance in Ghana: Implications for Sustainable Urban Development

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Abstract
Enhancing maintenance of urban roads is a condition that helps to promote sustainable urban development. It helps to put roads in good shape which in turns provide several economic, social, and environmental benefits in urban areas. This paper sought to develop economically feasible road maintenance interventions that can be resorted to enhance the maintenance of urban roads in Wa Municipality (Ghana). Data on four road classes were used. These roads were Class A (major arterial road), class B (minor arterial roads), Class D (distributor roads) and Class E (access roads). The HDM-4 economic analysis model was used to process and analyse the data. The overall data analysis of the roads was made to cover a 30 year period starting 2013.

The following treatment options were found as suitable to enhance the maintenance and sustainability of urban roads in the study area: Class A - "70mm thick overlay for every 11years at intervention level of 3.63 IRI", Class B - "40mm thin overlay for every 9 years at intervention level of 3.91 IRI", Class D - "40mm thin overlay for every 9 years at intervention level of 4.04 IRI", and Class E - "25mm surface dressing (resealing) for every 12 years at intervention level of 6.22 IRI". It is therefore recommended that public funds must be used judiciously with desirable portions allocated for timely road maintenance to enable the roads provide maximum economic and social benefits to the users.

Keywords: Ghana, Wa Municipality, road maintenance, sustainable urban development

1. Introduction

Roads are one of the major assets of every country. Road network infrastructure provides economic and social benefits for individuals, groups of people, companies and industries. It enables goods and services to be delivered timely and effectively, as well as enhances free movement of people. In urban areas, road networks are particularly important because these areas harbours more than half of the world's population and serve as a centre for businesses and many socio-economic activities which relies predominantly on roads. In general, it has been found out that maintenance of roads enhances economic growth and social benefits whilst poorly maintained road system destructs mobility, increases the rate of accidents, and aggravates isolation, poverty and vehicle operating cost (Emeasoba & Ogbuefi, 2013). According to the European Union Road Federation (2009), road maintenance is essential short-term transport policy that policy makers needs to pay particular attention to because it helps to enhance road safety and improves social welfare of the citizenry. Timely maintenance improves road condition, reduces road deterioration, vehicle operating cost, provides safety, keeps road services continuously and enhances environmental conditions (Robinson et al., 1998).

In Sub-Saharan African region, poor road maintenance has been found as a major problem that impedes over all development in the sub-region. A study conducted on Sub-Saharan African countries by Gwilliam et al. (2008) revealed that the region has poor conditioned roads compared to other regions of the world. The study indicated that the region has only 204 kilometres of road per thousand square kilometres of land area with only one quarter been paved. This condition fall short of the world average of 944 kilometres of road per thousand square kilometres with over half paved. The study further showed that the spatial density of roads in Sub-Saharan Africa is less than 30 percent which is lower than that of South Asia which is half paved, and that of North America which is two thirds paved. In addition to this, statistics on the condition of urban roads in Africa shows that most of the roads in African cities are sub-standard and plunged with many pot holes (Gwillian et al., 2008; Kumar and Barrett, 2008). According to Kumar and Barrett (2008), many African cities have poorly maintained road network with insufficient service lanes, deteriorating pavement, inadequate street lights and presence of many pot holes. In many African cities, the percent of unpaved roads is very alarming. Cities such as Kinshasa, Ouagadougou, Kigali, Bamako and Darka have only 10 percent, 11 percent, 12 percent, 24 percent and 30 percent of their road networks paved respectively (Gwillian et al., 2008). The resultant effects have been inefficient road network and the occurrences of many road accidents.

The situation in Ghana is not far from other sub-Saharan African countries which are struck with poor road maintenance. Statistics shows that only 28 percent of Ghana's road network is in good condition and 36 percent are in poor condition as against national expected level of 70 percent good and 10 percent poor (National Transport Policy, 2008 as citied in Tengey, 2009). Ghana as a country after independence witnessed a tremendous growth of road network due to higher vehicular population coupled with high population growth and large scale industrialisation (Dauda, 2012). This has created massive road congestion and therefore shifted the government attention from maintenance of existing road networks to new developmental road projects, where a chunk of road fund budget is diverted to. These developmental projects include; opening of access roads, road widening and road extensions. The little attention given to road maintenance in Ghana has caused many roads especially urban roads to develop weak structural capacity resulting in numerous road defects like potholes, hair cracking, rutting, depressions, break down of pavements and destroyed drainage systems (Owusu-Acheaw, 2012; Tengey, 2009). Despite these road maintenance problems in Ghana not much effort or studies have been carried out to come up with optimal road maintenance interventions to improve the situation. It is therefore against this backdrop that this paper is put together to provide road maintenance interventions to address this knowledge gap. Taken into consideration limited funds for road maintenance in Ghana, the objective of this paper is to develop economically viable road maintenance interventions that Ghana can resort to enhance the maintenance of its urban roads. The paper is centred on Wa Municipality which is grappling with severe road maintenance problems as a case study. Over 60 per cent of the road network in Wa Municipality are in poor condition with many of them not paved (Wa Unit of Department of Urban Roads, 2006).

2. Sustainable Urban Development and the Concept of Road Maintenance

Sustainable city is a development approach that is now receiving much attention in the world and been championed by many international organisations including the World Bank and United Nations. After the Brundtland Commission (WCED, 1987) conceptualised sustainable development to mean "development that meets the needs of the present without compromising the ability of future generations to meet their own needs (p. 43)", this ideology have been transferred to achieving sustainability in several dimensions of the world including urban development. Dwelling on the Urban 21 Conference held in 2000 at Berlin, Antrop (2006) defined sustainable city as a city that strive to achieve quality living standards in various components of the city such as economic, social, ecological, cultural, political, and institutional aspect without leaving a burden on future generations. Zheng (2005) gives broad characteristics of sustainable cities to include features such as maintaining balance among resources, promote social progress, economic use of resources, ecological security, flee flow of resources between inner and outer urban system, and in all satisfying the needs of urban development at present and at the same time meeting the city's future needs. Characteristic features such as a compactness, mixed land-uses, high density, diversity in activities, and sustainable transport system have also been highlighted to support sustainable urban development (Jabareen, 2006; Dumreicher et al., 2000).

Urban form theory which support the realisation of sustainable urban development advocate for compact transport system, living styles, and high density energy efficiency as vital requirements of sustainable urban development. It further emphasize that urban sustainability depends on the natural conditions of urban environment such as the urban scale and topography of urban land use, and other conditions including the proper functioning and structure of urban land use, and road network structure (Zhao, 2011). Sustainable urban transport takes greater part in the quest for sustainable urban development as all aspect of urban development to some extent utilises transport network (Barrett, 1996). In the pursuit of sustainable urban transport agenda, emphasis is most often given to public transport system, and measures that favours cycling and walking (Jabareen, 2006; Kenworthy, 2006). However, the 2012 world conference on sustainable development dubbed Rio+20 emphasized on the need for various sustainable development agendas to focus much attention on road safety (Watkins, 2012). This is because thousands of individuals are lost each year through road accidents and as a matter of fact road network takes a chunk of the various transport modes in the world with several development activities depending on them. This makes it imperative for various countries and cities of the world to embark upon regular road maintenance to keep their road network in good shape to enhance the welfare of the general public. According to Watkins (2012), maintenance of road network support sustainable development and for that matter sustainable urban transport by way of minimising casualties on roads, ensuring efficient movement of people and goods, improving social equity, health, resilience of cities, urban rural linkage, and productivity of goods and services.

In managing road network, Hooper (2001) has pointed out the following maintenance principles as critical that must be taken into consideration to ensure the efficiency of road network:

- Network safety coupling with statutory obligation and meeting user's needs;
- Network serviceability as to ensure availability, achieving integrity, monitoring reliability and enhancing quality;
- Network sustainability which includes minimizing cost of overtime, maximizing value to the community and maximizing environmental contribution.

Road maintenance activities or works have been conceptualised by the World Bank (2011) to generally cover four key activities such as routine, periodic, special and development works. The routine works are undertaken very frequently on roads especially on yearly bases and normally takes the form of cyclic and reactive works. Works undertaken of roads whose frequency is determined by the maintenance standards constitute the cyclic routine works. Typical examples of this form of routine maintenance include culvert cleaning and verge cutting which are mostly reliant on environmental effects rather than on traffic levels. The reactive works on the other hand covers works which intervention levels defined in the maintenance standards are used as a check to estimate the time maintenance is needed. Road patching carried out to address problems of cracks or pot-holes on roads are common examples of reactive works.

Periodic works as the name suggest are undertaken at relatively longer intervals but on regulated time frame. Resealing and overlay works carried out in response to measured deterioration in road conditions offers classical examples of periodic works on roads. Special works which is another category of road maintenance activities are undertaken to address unforeseen problems on roads that demand immediate attention (Emeasoba & Ogbuefi, 2013). They do not have specific periods that they are performed but undertaken when the need arise. In view of this, it is sometimes referred to as emergency works. Works which requires urgent attention such as removal of fallen trees which destructs flee flow of vehicles, destroyed culverts which blocks roads, broken down vehicles, and road works to address problems of landslide all fall under special/emergency works on roads. Development works or activities on the other hand cover all road construction activities that are within the development plan of an area. Typical example of this activity is the construction of by-passes, widening of road carriageways, tarring of roads in villages, and many more (World Bank, 2011). All these maintenance activities comes together to enhance the safeness of roads and makes roads easily accessible for all manner of activities (economic, social, environmental) to support the sustainable agenda of cities.

3. Methods and Data

The study was carried out in the WA Municipality in Ghana. Wa is the capital town of Upper West Region of Ghana. The Region shares boundary to the North with Boukina Fasso. The Wa Municipal area is bounded to the north-east by Wa East District, north-west by Nadowli District and south-west by Wa West District. It serves as a transportation hub for the north western part of Ghana with major roads leading to Kumasi in the south, north to Hamile and Boukina Fasso, north- east to Tumu and Upper East region (Wa Municipal Assembly, 2012). Figure 1 shows the location of Wa Municipality within the context of Ghana and figure 2 provides detailed structure of the road network in the municipality. The area has an estimated total population of 107,214 people with a growth rate of 1.9 per cent per annum (Ghana Statistical Service, 2010).

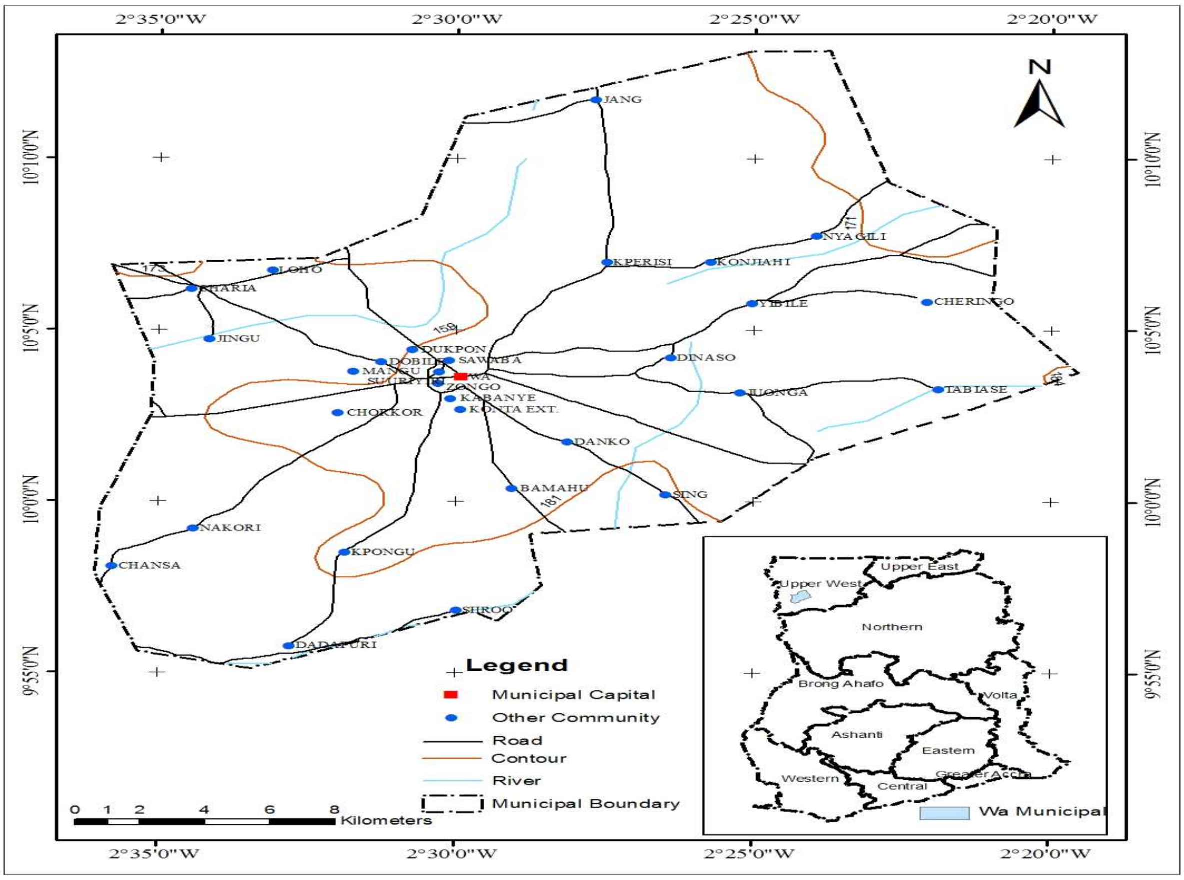
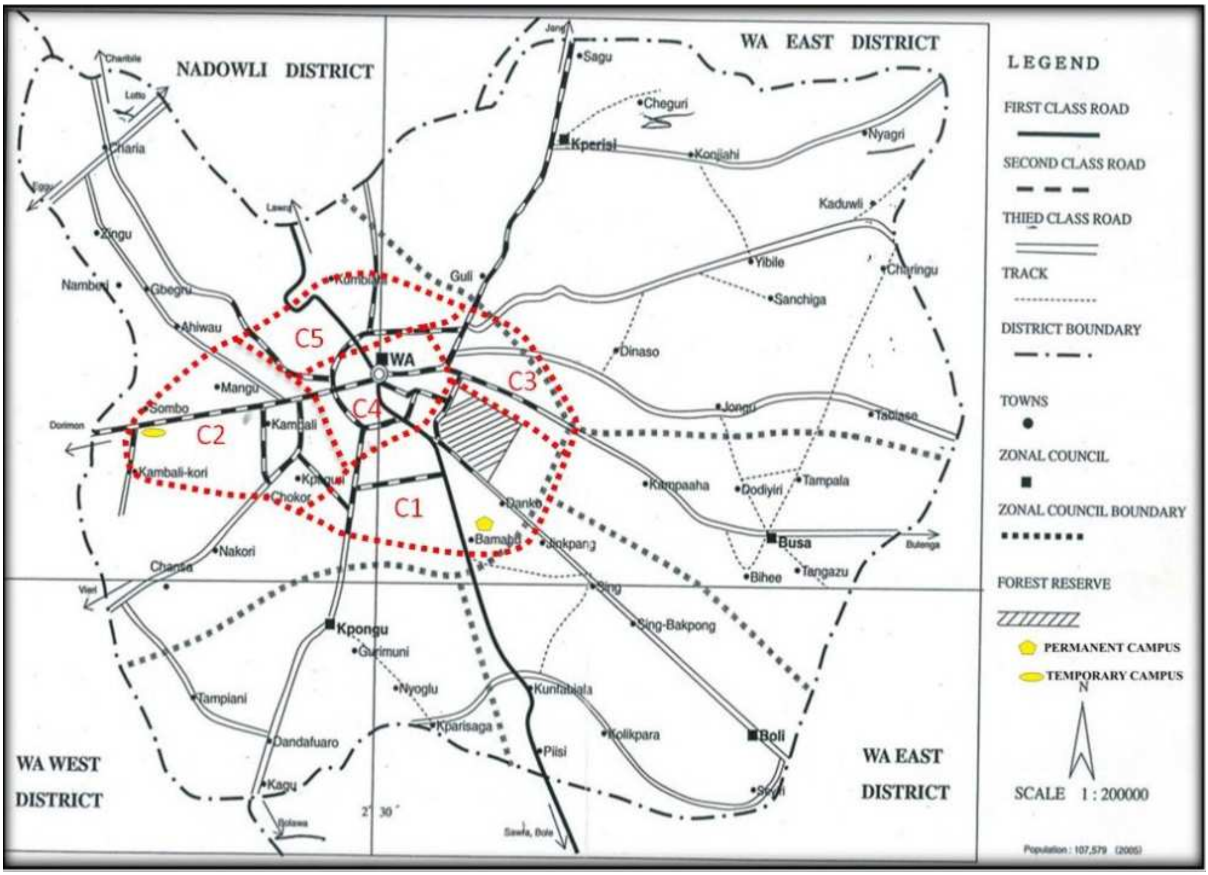


Figure 1: Map of Ghana showing Wa Municipality in regional and national context
Source: Aduah & Aabeyir (2012)



The red dotted areas show the road network at the core of the municipal area.

Figure 2: Road network in Wa Municipality

Source: Ahmed, 2011

The study was quantitative in nature and utilised the World Bank's Highway Development and Management (HDM-4) analytical model to analyse the data and come up with economically viable road maintenance standard. This model was used due to its strengths in predicting future road conditions and determining the required maintenance treatment, prioritizing investments among competing projects under budget constraints, and forecasting pavement performance and road user effect (Kerali, 2000). The analysis of the paper covered all the various classes of roads in Wa municipality. These roads were road class A (representing major arterial roads), class B (Minor arterial roads), class D (distributor or collector), and class E (access or local roads). Five possible periodic maintenance treatment types were used as alternative interventions namely 70mm thick overlay, 40mm thin overlay, surface dressing (resealing), and reconstruction as well as patching of severe damage area. These were prioritised according to the road class and traffic loading. Routine maintenance treatments such as patching and miscellaneous routine works were budgeted separately as base case scenario. In order to develop economically viable road maintenance intervals that fall within the annual budget of Ghana, the 2010 annual budget allocated to Wa municipal roads unit towards routine and periodic maintenance activities was relied upon in the paper. Data for the paper were obtained from Ghana Highway Authority (GHA) and Department of Urban Roads (DUR).

In arriving at economically feasible maintenance interventions, various economic evaluation analyses as suggested by Kerali (2000) were conducted. These analyses included the calculation of Net Present Value (NPV), Internal Rate of Return (IRR), Cost Benefit Ratio (CBR), Total Net Benefit (TNB), Present Value of Agency Capital Cost (CAP), and Road Agency Coast (RAC). Road data considered for configuration in the HDM-4 model included traffic volume, vehicle composition, and vehicle operating costs in addition to some parameters from HND-4 default values such as International Roughness Index (IRI). Other parameters considered were condition data in terms of roughness, pavement types, maintenance alternatives and their unit costs, budgets, climate and road construction history. Additional data utilised were 10 per cent discount rate for 30 years analysis period, flat straight road at sea level representing roads in flat/ rolling terrain, rise and fall 30m/km and curvature of 50 deg /km. Others were CBR of 5 to 10 percent based on road class and structural number between 0.95 and 3.0 from HDM-4 default with initial level of roughness taken to be 2 IRI and terminal at 12 IRI where rainfall level reads 200mm/ month.

A comparison of maintenance alternatives were conducted with the base case been the ‘do minimum scenario’. In this regard, the routine maintenance was used as the ‘do minimum alternative’ to represent the base case only against other periodic treatment alternatives. This was applied to all the various road classes to determine the best maintenance treatment alternatives suitable for the various roads. The roads were categorised into treatment standard with treatment cost. The treatment standards specifies the various treatment options applicable to the road classes based on initial roughness of 2 to 4 IRI. Intervention levels for triggering maintenance were defined whereas maintenance operations such as patching, edge break repair, and other routine works were scheduled and triggered annually.

4. Results and Discussion

The results generated by the HDM-4 economic model, proposed for each of the road classes (Road Class A, B, D and E) the optimal economic maintenance interventions that can be carried out to enhance the sustainability of the roads. These results reflects the outcome of rigorous economic analysis that took into considerations various road treatment options and indicators such as total transport cost, the average condition of the pavement surface in terms of progression of average roughness by section for both "before treatment and after treatment" under deterioration and works effect. The percentage area of carriageway damaged (cracking), number of potholes and schedule alternative interventions were also factored in. Table 1 gives a summary of the results provided by the HDM-4 economic model for optimal road maintenance interventions in Wa Municipality.

Table 1: Summary of results from HDM-4 analysis on proposed maintenance standards

Road Class	Treatment Alternative	ttc	IRIkm/m B/T	IRIkm/m A/ T	% Cracks	No. PoH	Total Net Benefit
A	Base alternative (Routine Only)	1319.946					
	Patch Severe Damage Areas	1464.329					-144.383
	Reconstruction	1310.291	9.07	1.2	49.51	343.01	9.655
	Surface Dressing (Resealing)	1280.819	2.6	2	3.66	2.57	39.127
	70mm Thick Overlay	1280.547	3.63	1.8	44.04	33.03	39.399
	40mm Thin Overlay	1279.579	2.78	1.8	10.19	2.65	40.367
B	Base alternative (Routine Only)	485.497					
	Patch Severe Damage Areas	529.878					-44.382
	Reconstruction	486.011	11.52	1.2	49.4	400.72	-0.514
	Surface Dressing (Resealing)	466.289	3.32	2.5	11.51	2.63	19.207
	70mm Thick Overlay	466.615	4.77	1.86	49.4	70.39	18.882
	40mm Thin Overlay	464.705	3.91	1.8	37.08	16.13	20.791
D	Base alternative (Routine Only)	187.194					
	Patch Severe Damage Areas	205.856					-18.663
	Reconstruction	195.924	16	1.4	48.52	869.52	-8.73
	Surface Dressing (Resealing)	181.634	3.77	2.5	30.17	1.76	5.56
	70mm Thick Overlay	182.303	5.63	2	49.36	131.96	4.891
	40mm Thin Overlay	181.475	4.04	2	40.94	10.05	5.718
E	Base alternative (Routine Only)	61.741					
	Patch Severe Damage Areas	65.819					-4.078
	Surface Dressing (Resealing)	58.989	6.22	2.5	49.31	108.2	2.752
	70mm Thick Overlay	60.689	12.24	2.5	49.3	362.79	1.052
	40mm Thin Overlay	59.387	7.45	2.5	49.31	170.98	2.354
	Ttc = Total Transport Cost						
	B/T = Before Treatment						
	A/T = After Treatment						
	No PoH = Number of Potholes						

Source: Data analysis (2013)

4.1 Road Class A (major arterial roads)

From Table 1, 40mm thin overlay treatment option appeared the most optimal choice. This was to be applied when the roughness on the pavement surface condition reached 2.78IRI and should be performed at every 8 years intervals to obtain a predicted roughness level of 1.8 IRI after the intervention. Other alternative interventions such as application of 70mm thick overlay at every 11 years and surface dressing at about every 6year (6.4 years) proved equally economically viable in terms of their net present value (NPV) and total transportation cost. They had marginal increases in agency cost and less road user cost, hence having positive results in the following parameters: NPV/RAC and NPV/CAP (Table 2). The value for the IRR showed an increase above the discounted rate which was set at 10%.

Table 2: Summary of economic indicators for Class A roads

	Present Value of Total Agency Costs (RAC)	Present Value of Agency Capital Costs (CAP)	Increase in Agency Costs(C)	Decrease in User Costs (C)	Net Exogenous Benefits (E)	Net Present value (NPV= B + E + C)	NPV/Cost Ratio(NPV/RAC)	NPV/Cost Ratio(NPV/CAP)	Internal Rate of Return (IRR)
Base Alternative	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
patch severe damage areas	0.000	0.000	-0.006	-18.668	0.000	-18.663	zero cost	zero cost	No Solution
Reconstruction	0.765	0.747	0.759	-7.971	0.000	-8.730	-11.417	-11.693	-5.1 (2)
Sd	2.111	2.104	2.105	7.665	0.000	5.560	2.634	2.643	29.2 (1)
Thick Overlay	1.550	1.547	1.545	6.436	0.000	4.891	3.155	3.161	30.5 (2)
Thin Overlay	2.083	2.082	2.078	7.796	0.000	5.718	2.745	2.746	30.5 (2)
						Figure in brackets is number of IRR solutions in range -90 to +900			

Source: Data analysis (2013) *SD: Surface dressing (resealing*)

However, application of reconstruction at every 21 years showed the least value of NPV and had a limited economic benefit as a result of subsequent suspension of maintenance activities (Table 2). This rendered much increase on road surface deterioration which as a result increased road user cost. In other way round this means that the condition of the pavement has not deteriorated enough to the extent that needs reconstruction. Application of such treatment could be a waste of resources. Furthermore, patching severe damaged areas triggered at every month when five potholes developed at every kilometre produced similar results as the base case. This outcome can be due to the criteria used to schedule the patching operations on the road pavement surface. This suggests that this option should not be used as final treatment alternative but rather a measure of temporary intervention to improve surface quality awaiting other periodic maintenance treatment.

All the three chosen treatment alternatives (40mm thin overlay, 70mm thick overlay, and surface dressing) proved viable but ideally only one should be used. In view of this, thorough analysis was further carried out on the three treatment alternatives to select the optimum economic treatment among them. Based on the findings of the paper, the 40mm thin overlay applied in every 8years had 10.19 per cent cracking, 2.65 number of potholes, intervention level of 2.78 IRI, total transportation cost of 1,279.579 million pounds, and total net benefit of 40.367 million pounds. With respect to the 70mm thick overlay, it was applicable in every 11 years with trigger intervention level of 3.63 IRI. It had about 33 number of potholes developed with a percentage cracking level of 44.04. This clearly indicated that the carriageway has deteriorated enough to warrant intervention. Surface dressing on the other hand was set to be used in about every 6 years (6.4 years) at a trigger level of 2.6 IRI. At this level, the pavement surface experienced only 3.6 per cent of average cracking and about 3.0 numbers of potholes. This showed only limited deterioration and therefore proved not to be a good choice. From engineering point of view, the 40mm thin overlay contains the highest total net benefits and the least total transport cost, however cannot be the best choice due to the following reasons:

- Class A roads contains heavier axle load trucks, hence thin overlay may experience early cracks, rutting and shoving.
- The numbers of potholes and cracking set for standard to trigger intervention like 40mm thin overlay at that particular period have not been met based on the level of pavement surface deterioration recorded.
- Applying this option may cause waste of resources since the condition warrant for only patching at that period.

It was realised that the 70mm thick overlay has a longer period to commence intervention and enough deterioration which can resist free flow of traffic, impede comfort, and safety. Delaying such condition may escalate cracking percentage and number of potholes which can lead to reconstruction, therefore this condition calls for intervention and represent a fair distribution of transport cost for both road agency and road users. Overall, since the major arterial roads in the Wa Municipality have high traffic loading with heavy duty vehicles, 70mm thick overlay appeared to be the best road maintenance option and serve as a strategy to maximise benefits to road users.

4.2 Road Class B (minor arterial roads)

Application of the 40mm thin overlay in every 9 years was selected as an economically optimised alternative from the HDM-4 results. This implies that applying such treatment would provide accurate riding quality to vehicle operators. It further reduced road user cost and then has the maximum net benefits as compared to the other alternatives such as surface dressing (resealing), 70mm thick overlay and reconstruction. The surface dressing was applicable in about every 7 years (7.3 years) with an intervention level of 3.32 IRI. The 70mm thick overlay triggered in every 12 years at an intervention level of 4.77 IRI whilst the reconstruction was applicable in every 23 years with intervention level of 11.52 IRI. Analysis in Table 3 showed that with the exception of reconstruction and patching of damaged areas which were considered to be non-feasible in terms of not having adequate economic benefit, the three other alternatives had almost the same net benefits, total transport cost and NPV's.

Table 3: Summary of economic indicators for Class B roads

	Present Value of Total Agency Costs (RAC)	Present Value of Agency Capital Costs (CAP)	Increase in Agency Costs(C)	Decrease in User Costs (C)	Net Exogenous Benefits (E)	Net Present value (NPV= B + E + C)	NPV/Cost Ratio(NPV/RAC)	NPV/Cost Ratio(NPV/CAP)	Internal Rate of Return (IRR)
Base Alternative	0.008	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
patch severe damage areas	0.000	0.000	-0.007	-44.389	0.000	-44.382	-250,236.292	zero cost	No Solution
Reconstruction	2.270	2.224	2.262	1.748	0.000	-0.514	-0.226	-0.231	9.6 (1)
Sd	6.328	6.321	6.321	25.528	0.000	19.207	3.035	3.039	29.3 (1)
Thick Overlay	4.288	4.285	4.280	23.162	0.000	18.882	4.403	4.407	37.2 (1)
Thin Overlay	5.128	5.127	5.120	25.911	0.000	20.791	4.055	4.056	36.8 (1)
						Figure in brackets is number of IRR solutions in range -90 to +900			

Source: Data analysis (2013) *SD: Surface dressing (resealing)*

In pursuing further to select the optimum maintenance alternative, it was observed that the level of cracking before intervention commences varies among various treatment options. This might have a correlation with the period of intervention. On surface dressing (resealing), the percentage of cracking and even the number of potholes looked so limited to call for intervention. This is because applying such intervention will transfer all the cost of the intervention from the road users to the agency which is not appropriate. The 70mm thick overlay had about 50 per cent of cracking and about 70.39 numbers of potholes. This could increase the roughness level along the pavement surface before the commencement of intervention. In this case, the road agency may transfer the cost of the intervention to the road users, hence such standard may not be a better choice. Considering the application of 40mm thin overlay, the condition of the road surface after 9 years experienced the required deterioration that can warrant an intervention and reasonably economical to both the road agency and the road users. This intervention served as an ideal economic treatment to be applied. The application of the reconstruction treatment option resulted in the attainment of the highest total transport cost and therefore not economical. This was not a good road treatment option for the minor arterial roads in Wa Municipality. In engineering perspective, it implies that the road has not deteriorated to an extent that warrant reconstruction or the permissible interval is too long before intervention commences.

Furthermore, regarding deterioration and works effect, it was realised that the application of the above treatments as interventions indicate a total reduction of roughness on the road carriageways. For instance, application of 40mm thin overlay every 9 years and application of 70mm thick overlay every 12 years reduced roughness level from 3.91 and 4.77 IRI to 1.8 IRI respectively. The application of surface dressing on the other hand gave a reduction of 3.32 IRI to 2.5 IRI as shown in Figure 3. Based on the analysis of the HDM-4 model and the finding of the paper, the application of the 40mm thin overlay maintenance option was found as the optimal economic maintenance option for Road Class B.

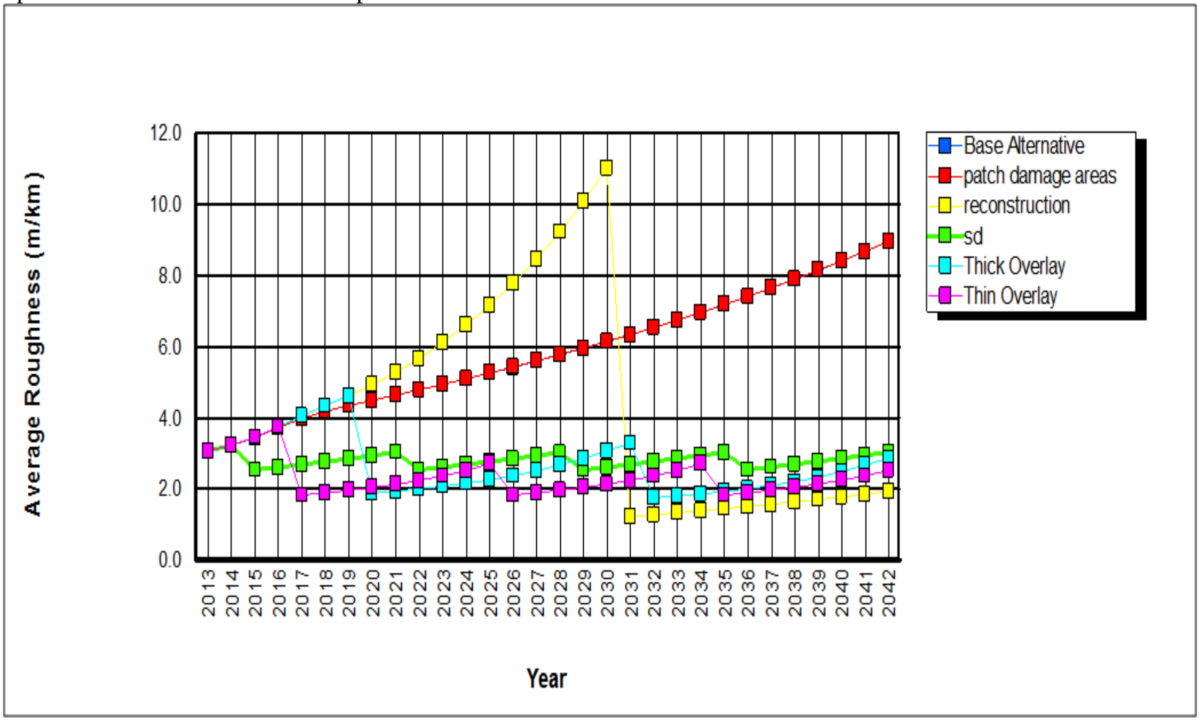


Figure 3: Average roughness by section graph

Source: Data analysis (2013)

4.3 Road Class D (distributor roads)

This road class had similar maintenance results like road class B. This can be attributed to the similar nature of the traffic capacities on the two carriageways. The optimised maintenance treatment from the HDM-4 results proposed 40mm thin overlay to be a higher economically justifiable option to provide benefits for this road. Among the various treatment options such as patching of severe damaged areas, reconstruction, surface dressing, and 70mm thick overlay, the application of 40mm thin overlay applied in every 9 years with a trigger roughness level of 4.04 IRI was recommended on the bases of haven the highest NPV and less total transport cost. Comparatively, the 25mm surface dressing applied about every 8 years (7.8 years) at 3.77 IRI and 70mm thick overlay applied every thirteen (13) years at 5.63 IRI were equally best options since their savings in user cost were much higher with almost equal benefits and total transport costs. Considering the other parameters such as percentage cracking and number of potholes developed on the carriageway, surface dressing had less than the number of potholes that warrant intervention but had enough cracking. Since cracking graduates into potholes on pavement surfaces when left unattended for a longer period than creating serious roughness, surface dressing ended up not been the best choice. In the case of applying 70mm thick overlay, the pavement surface had numerous potholes with almost 50 per cent cracking. This may escalate road user cost and hence not recommended for use. Consequently, the 40mm thin overlay fall within the predicted number of potholes which require intervention and a reasonable percentage cracking. Further increased of time may cause multiples of potholes and increased excessively the roughness level. In this case, 40mm thin overlay was recommended as the best option to apply.

Reconstruction occurring every 25 years with 16.0 IRI resulted in negative NPV and high total transport cost. This was because it had higher agency cost than savings in user cost. This takes a longer period before maintenance can be applied and therefore brings higher cost to road users. It was observed that the application of reconstruction treatment option on various road classes was not economical. The following reasons came out as plausible cause for that:

- The period of applying reconstruction seems to be too long. This cause the road to deteriorate to an extent that it increases the vehicle operating cost.
- The traffic capacity and the loading on the roads are not so high enough to trigger for reconstruction.
- The level of deterioration was too low and hence application of reconstruction might be a waste of resources.

Analysis of the extent of deterioration and works effect on the Class D roads demonstrated that the road experienced reduction in roughness whenever there is treatment intervention. This implies that application of treatment alternatives reduce pavement surface roughness and hence provide quality riding on the road surfaces. This on other hand reduces vehicle operating cost, travel time cost; enhance safety and comfort, and results in reduction of accident cost. This is contrary to patching of severe damage areas which ought to be applied in every three months. This gives the same level of maintenance as the base case (routine only) with almost similar total transport cost. The implication is that traffic volume per day and the loading applying on the road carriageway are too high to be sustained by only routine activities and pothole patching. All these analysis supported the application of the 40mm thin overlay as the optimal treatment option for Road Class D.

4.4 Road Class E (access or local roads)

The optimal maintenance intervention predicted by the HDM-4 model for local roads carrying low traffic volume was the application of the surface dressing (resealing) every 12 years when roughness triggered at 6.22 IRI. The other maintenance option that came closer to this intervention was the 40mm thin overlay applicable in every 14 years when surface roughness triggered at 7.45 IRI. In this regard, the 70mm thick overlay applied every 19 years when the level of roughness is at 12.24 IRI has a limited NPV as shown on Table 4. Surface dressing (resealing) and 40mm thin overlay treatment options were found to provide maximum economic benefits when applied to improve the riding quality of "Class E" roads.

Table 4: Summary of economic indicators for Class E roads

	Present Value of Total Agency Costs (RAC)	Present Value of Agency Capital Costs (CAP)	Increase in Agency Costs(C)	Decrease in User Costs (C)	Net Exogenous Benefits (E)	Net Present value (NPV= B + E + C)	NPV/Cost Ratio(NPV/RAC)	NPV/Cost Ratio(NPV/CAP)	Internal Rate of Return (IRR)
Base Alternative	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
patch severe damage areas	0.000	0.000	-0.003	-4.081	0.000	-4.078	-94,048.262	zero cost	No Solution
Sd	0.511	0.482	0.508	3.261	0.000	2.752	5.387	5.709	40.9 (2)
Thick Overlay	0.310	0.308	0.307	1.359	0.000	1.052	3.397	3.418	16.9 (2)
Thin Overlay	0.464	0.463	0.462	2.816	0.000	2.354	5.069	5.088	33.7 (2)
						Figure in brackets is number of IRR solutions in range -90 to +900			

Source: Data analysis (2013) *SD: Surface dressing (resealing)*

In terms of patching severe damaged areas, negative results were obtained in all parameters which then resulted in zero cost at NPV/CAP and no solution regarding IRR (Table 4). Since the road contains less traffic, surface dressing (resealing) came out as the best recommended maintenance option to be used. The reason is that the intervention period occurred when potholes level increased (about 108) with 50 per cent surface cracking. This made it an ideal choice to reduce total transportation cost and provide much road user benefit.

Regarding deterioration and works effect, the road surface condition improved as soon as an intervention occurs. The application of surface dressing (resealing) treatment option resulted in the road surface condition improving to the level of 2.5 IRI. This rapidly rose again within few years before the scheduled period. Although some deterioration occurred on the road but this was not significant. The deterioration could be a result of the base material not having enough strength to withstand the increase in traffic or effects of weather condition during rainy season.

5. Conclusion and the Way Forward

The paper has demonstrated that the road network in Wa Municipality is in precarious condition which is contrary to the road safety campaign been championed by United Nations (Watkins, 2012). To improve the road condition in Wa Municipality (Ghana), the paper discovered some economic optimal road maintenance treatments that have to be undertaken. For Class A roads (major arterial roads), the application of the 70mm thick overlay for every 11years at intervention level of 3.63 IRI came out as desirable maintenance treatment. For the other road classes the following results were obtained: Class B roads (minor arterial roads) - "40mm thin overlay for every 9 years at intervention level of 3.91 IRI", Class D roads (distributor or collector roads) - "40mm thin overlay for every 9 years at intervention level of 4.04 IRI", and Class E roads (access or local roads) - "25mm surface dressing (resealing) for every 12 years at intervention level of 6.22 IRI". The implication of these findings to the sustainable development of Wa Municipality is that to put the area on firm grounds to pursue its sustainable agenda, much attention should be paid to frequent road maintenance activities such as those discovered by the paper. This is because road network serves as important infrastructure that virtually all the activities in Wa Municipality depend on.

To enhance the road maintenance situation in Wa Municipality the following recommendations have been suggested. Budgets allocated for road maintenance should be aligned for specific maintenance activities such as for paved and unpaved roads. This will ensure efficient value for money and that the road network will receive enough funds for economically justified maintenance works at affordable standards, and timely execution and completion by contractors. The management of the Department of Urban Roads must set aside funds to conduct regular inventory and road condition survey. This will help to frequently update its road network data records, and identify the various roads that need urgent maintenance. Budgetary allocation from the Road Fund Secretariat of Ghana for road maintenance should be based on the needs of maintenance treatment of various road classes than depending on availability of funds due to budget constraints. The Road Fund Secretariat, Ghana Highway Authority and Department of Urban Roads should collaborate to find practical ways that various urban roads can be managed commercially to generate much funds for road maintenance.

In sum, the paper ends with advisory remarks that the road agencies in Ghana should not wait for urban roads to completely deteriorate before applying the various maintenance interventions. Embarking of regular maintenance works will save much money than allowing the roads to totally destroy before coming up with measures to save the situation because "prevention is better than cure".

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