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Dodging the Potholes: The Spatio-Distribution and Socio-Economic Impacts of Potholes in the Residential Areas of Gweru, Zimbabwe

Mutekwa Timothy, Matsa Mark and Kanyati Kudzanai
Department of Geography and Environmental Sciences, Midlands State University, Gweru 9055, Zimbabwe

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Abstract: Since the year 2000, the city of Gweru has had an unprecedented proliferation of unattended potholes on most of its roads These potholes have caused discomfort to the motoring public, caused death to others and damaged vehicles. This paper presents the results of a study that sought to establish the spatial distribution of potholes and determine their socio-economic impacts in Gweru's residential areas. Pothole location and dimensions were measured in the field whilst interviews and questionnaires were administered to vehicle owners, motor mechanic experts, drivers and the travelling public to determine their socio-economic and mechanical impacts. Stratified, convenience and purposive sampling methods were used in the selection of study streets and respondents to questionnaires and interviews. Results revealed that potholes are more concentrated in high density residential areas compared to low density areas. This is primarily due to the substandard construction of roads done in high density residential areas. Other causes of pothole formation identified during this study are poor drainage on the roads, rainfall impact, advanced age of roads, poor or lack of maintenance, type and volume of traffic as well as the effect of tree-root prying on paved surfaces. It is recommended that Gweru City Council enters into partnerships in road construction. The city should also establish fundraising projects to augment its budget. This would help ease problems of service delivery including road maintenance. Signposts can be erected to warn drivers about these hazards in the most affected streets and suburbs. It is also important that council set aside a toll-free telephone line link with road users so that areas where new potholes have been detected are quickly reported and attended to. This will not only save lives but also reduce road maintenance costs and vehicle damage.

Key words: Pothole, city council, road maintenance, high-density suburbs.

1. Background

There are about 88,100 km of classified roads in Zimbabwe, 17,400 km of which are paved [1]. About 8,190 km of the road network are urban roads. These roads carry an estimated 80% to 90% of the country's passenger and freight transport making road transport the dominant form of transport in the country [2]. Despite their importance, most roads in Zimbabwe are poorly managed and badly maintained. Although there is no accurate information about the current condition of Zimbabwe's road network, the fact of the matter is that it has significantly deteriorated especially since the late 1990s due to the economic meltdown that characterised the period 2000-2008 leading to lack of resources particularly funding for routine and periodic maintenance [1]. Only about 24% of Zimbabwe's entire road network was in "good" condition in 2005 and 40% was in "poor" condition [3]. The Department of Roads' estimate of the condition of the road network based on extrapolation of the pre-2005 data and informal visual surveys in 2009 established that only about 20% of the total network was still in good condition. Urban roads are among those that were hardest hit by the lack of funding for maintenance and therefore have experienced the worst levels of

Corresponding author: Mutekwa Timothy, master, main research fields: urban transport challenges, forest governance and rural livelihoods, climate change and conservation farming, environmental pollution and control. E-mail: mutekwat@msu.ac.zw.

decline [1].

The main problem that has negatively affected the condition of Zimbabwe's urban roads is the presence of potholes.

These are however an increasingly common problem associated with roads worldwide. The presents of potholes and the general poor state of roads are a great source of irritation for most local councils and municipalities, as they do not have adequate resources to effectively fix them [4]. Potholes constitute a major concern with regards to road conditions because they develop quickly and are a serious hazard to the motoring public that ply local and transnational highways [5].

Vidal [6] argues that the poor condition of roads in Africa particularly the development of potholes is due to the extremes of sun and rain that bake the roads dry or leave them cratered and impassable. Pothole development is accelerated by the eating away of the bottom and sides of the pothole by rain water. As chunks of pavement peel off, the pothole grows larger and deeper and spreads quickly across the entire roadway if its growth is not timeously arrested [7]. On South African roads, pothole development has accelerated considerably due primarily to reduce preventative maintenance of many of these roads, combined with particularly wet periods during rainy seasons and rapidly increasing numbers of heavy vehicles [8]. Potholes can grow to meters in width, though they usually only become a few centimetres deep, at most. Roads strewn with potholes are a cause for concern to vehicle owners, drivers and the travelling public. They lead to high vehicle operating costs and lengthy travel times [2, 9-12]. VOCs (vehicle operating costs) include various direct costs to operate a vehicle such as maintenance, tires, fuel, labour, and capital costs. Roads in poor condition raise costs of operation because they reduce fuel efficiency, damage the vehicles leading to higher maintenance costs, reduce the life of tires, reduce vehicle utilization because of lower speeds, reduce the life of the truck and increase the risk of accidents [13, 14]. The bottom line is that motorists incur huge expenses whilst the travelling public experience great discomfort when travelling on roads strewn with potholes [15].

Potholes have become a topical issue in Zimbabwe as newspaper reports abound of motorists who have gone to the extent of suing some local councils for pothole induced damages to their vehicles. In 2010, a Zimbabwean banker won a court case against Harare City Council after her Mercedes Benz vehicle got damaged by a pothole along one of the major city roads [16]. On the other hand, a Bulawayo city high court judge had his car repaired by government after he threatened to sue the Bulawayo City Council for pothole damages to his car [17].

The problem of potholes in Zimbabwe has not been for Harare and Bulawayo alone as illustrated by court cases but for all towns and cities. Gweru City Council, for example, has faced challenges in constructing and maintaining its roads over the years. Several roads have had potholes for over a decade now. Meaningful road maintenance programmes in Gweru were carried out prior to the hyperinflationary period of 2000-2008. Since then the problem of potholes has remained a perennial issue and they are now a menace in the city's roads. In recent years, Gweru city council has been patching potholes with soil therefore providing just a temporary respite as the soil is easily scooped away by vehicle wheels and rain water particularly in the summer season. There have been very few studies in Zimbabwe focusing on potholes and their impact on road users, vehicle owners, local authorities, vehicles themselves and the generality of the public. Based on the study of potholes in some selected suburbs in Zimbabwe's third largest and centrally located city of Gweru, this paper seeks to fill part of this lacuna by analyzing the nature, distribution and the socio-economic impacts of potholes in the city of Gweru.

1.1 The Pothole Formation Process

Potholes are partly caused by damage from weather

related conditions. They occur when extreme shifts in weather patterns leave the ground unstable and prone to splitting. They are also caused by different weights from vehicles. Potholes may be accompanied by severe cracking and deformation or distortion of the surface around the pothole, indicating a deep-seated cause for pothole formation [18].

Where little deformation is observed in the vicinity of the pothole, the cause is likely to be the entry of water through superficial cracks in the road pavement and deterioration of only the surfacing and upper structural layers of the pavement [19]. Overtime, vehicles passing over the road force water deeper through the soggy roadbed, eventually eroding parts of it. As the roadbed continues to erode, the asphalt begins to sink into the eroded portions and eventually cracks under the continued impact of vehicle tyres. This process is summarised in Fig. 1.

1.2 Other Causes of Potholes

Other causes of pothole formation are high traffic volumes, roadbed base failure, and drainage problems near or under the roadway, petroleum products such as diesel or gasoline spilling on the asphalt, frost boils, and utility failures [7]. In Europe, freeze-thaw action has been cited as one of the major contributors to tarmac surface cracking which results in weakening of the road surface leading to pothole formation. There has been a 90% increase in the number of potholes on UK roads since the severe winter weather struck in 2009 [13]. The icy conditions have resulted in a huge surge in the number of potholes on Britain's roads due to the freeze and thaw effect.

Tarred roads are particularly vulnerable to the erosive effects of water, causing the number of potholes forming each day to rise by 70% on South African roads in heavy or continuous downpours [20]. In February 2008 alone, about 5,200 potholes were reported to have formed in Johannesburg in the summer season [20]. The development of potholes on South African roads has accelerated considerably due primarily to reduced preventative maintenance being applied to many roads combined with particularly wet periods during rainy seasons and rapidly increasing numbers of heavy vehicles [8]. Besides weather conditions, pothole formation on some Zimbabwean roads have been exacerbated by the end of the lifespan of many tarred roads. It has been observed that the city of Harare has a backlog of road maintenance dating back to 2002 showing great negligence on road maintenance by city councils of Zimbabwe [21].

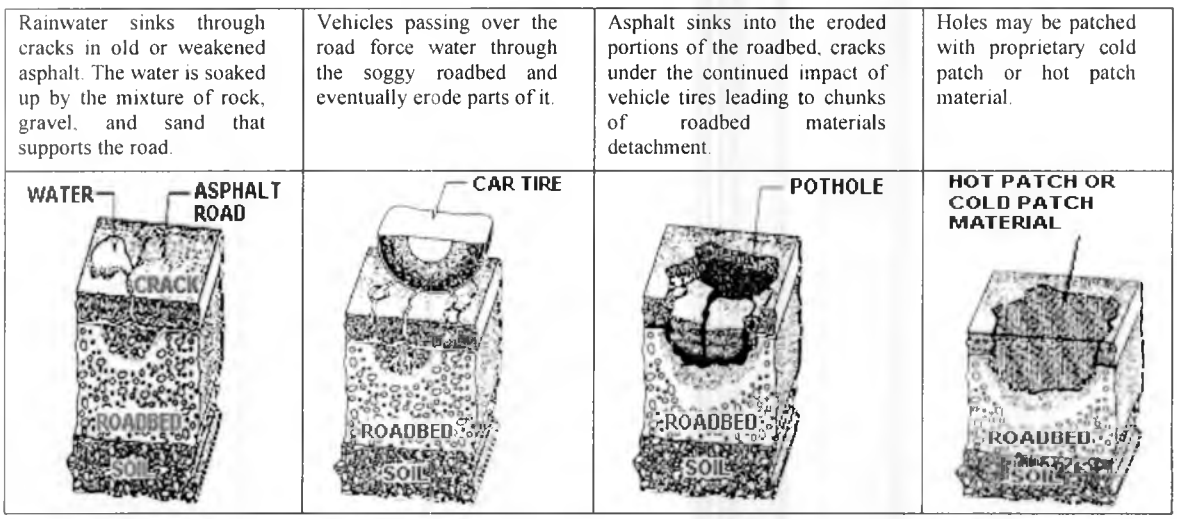

Fig. 1 The process of pothole formation. Source: Ref. [19].

2. Materials and Methods

2.1 Study Area

The study was conducted in Gweru, the third largest city in Zimbabwe in terms of functions such as commerce, transport and industry [22] and the capital of the Midlands province. It is about 170 km from Bulawayo and 280 km from Harare along the Harare-Bulawayo road and railway line. Gweru was established in the late 1890s and became a municipality in 1917 [23]. This city is Zimbabwe's main road and railway central junction with rail radiating to Harare, Bulawayo, Masvingo, Zvishavane, Shurugwi and the South-East Lowveld. The city has the country's biggest marshalling yard at Dabuka.

Gweru's altitude is on average 1,430 meters above sea level [24]. Its climate is characterized by a dry season that extends from May to October and a wet season that stretches from November to April. The average annual rainfall is 670 mm. The average highest and lowest temperatures of Gweru are 27 °C and 16 °C, respectively [24]. Gweru is located along the rich mineral belt of the Great dyke and therefore both formal and informal particularly chrome and gold mining are major activities in its environs. The city is dominated by unstable silicate clay soils that shrink and crack during the dry season and compact during the wet summer season [25].

Gweru has a population of 146,073 people [26]. Its major industries include Zimbabwe Alloys, Bata Shoe Company, Cold Storage Commission, Zimglass and BOC Gases. According to the Zimbabwe Standard newspaper of October 10, 2010, some of the major companies like Radar Castings, Zimbabwe Casting, Kariba Battery Manufacturers, BOC Gases and Zimbabwe Alloys have shut down because of the land reform related economic meltdown of the 2000-2008 period.

Gweru's suburbs are divided into high, medium and low density residential areas. These divisions originated during the colonial era and were based on skin colour or racial lines until the achievement of black majority rule in 1980. Although suburban racial integration has significantly improved since then, the legacy of differential infrastructure and services provision still remains to this day. Among the high density suburbs are Mkoba, Mtapa, Senga, Nehosho, Mambo and Ascot, most of which are located to the west of the city, close to heavy industries and were designed for the indigenous black residents. Infrastructure and service provision in these suburbs was and remains the most inferior. It also deteriorates rapidly due to its inherent poor quality and overutilization. The medium density suburbs that are also moderately provided for infrastructure and services wise include Nashville, Lundi Park, and Northlea which were originally designed for members of the coloured community. The low density residential suburbs of Harben Park, Ridgemont, Kopje and Windsor Park among others were designed for the population of European origin or decent and therefore have the most superior infrastructure and services. The locations of the sampled residential areas in the city of Gweru are shown in Fig. 2.

2.2 Data Collection Methods

Nine semi-structured interviews were held with different commuter owners, private car operators, mechanics and the Gweru city council roads engineer soliciting for information on socio-economic problems associated with the many pothole-strewn roads in the city. The interviews were held on different days to cater for the varied work schedules of the targeted interviewees.

The six commuter omnibus owners interviewed were conveniently selected and they represented all residential areas sampled for study. They were chosen on the basis of their knowledge of repairing costs they encounter as they operate the public transport vehicles business. Two mechanics were purposively sampled and interviewed about nature of vehicle damage caused by potholes and their costs to commuter operators.

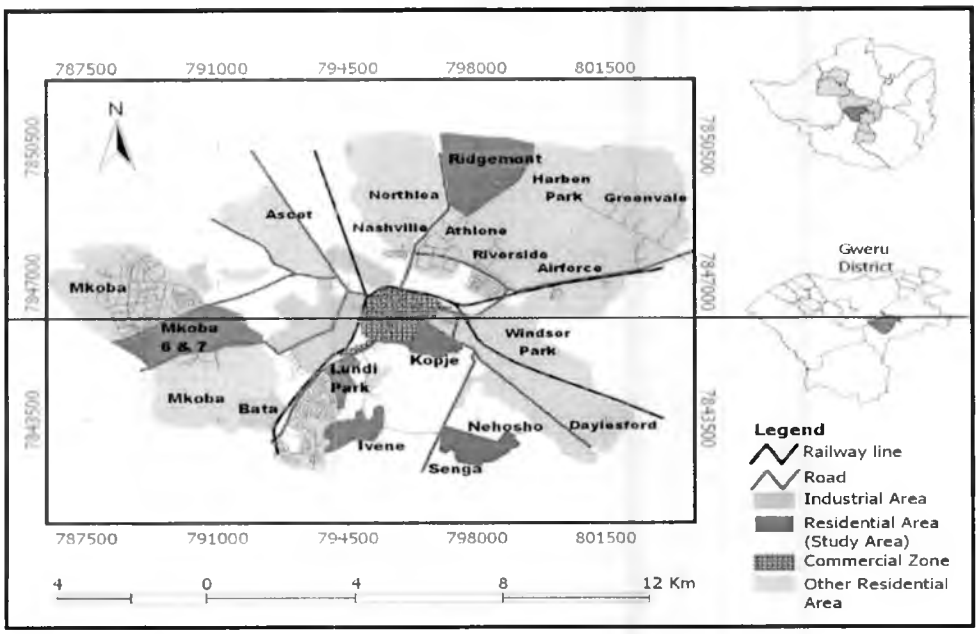

Fig. 2 Location of the city of Gweru (study area).

The Gweru city roads engineer was also interviewed to get information about the management and financing of road construction and maintenance in the city of Gweru. The interview method was advantageous in that it provided in-depth information about types of vehicle defects, related costs and road construction and maintenance issues.

Questionnaires were self-administered to passengers and commuter omnibus drivers. Forty volunteering respondents who were present during the time of the survey at the city commuter omnibus ranks were randomly selected and requested to fill-in the questionnaires at the ratio of 30 questionnaires for commuter drivers and 10 questionnaires for passengers. The drivers were judged to have useful information on pothole problems owing to the nature of their work whilst the passengers provided an overview of the socio-economic impacts of potholes to the commuting public.

Field measurements were conducted to determine the specific position, nature and dimensions of the potholes on studied roads in different residential suburbs. The sampled streets are shown in Table 1. The exact location of the potholes on the roads was determined using a hand-held GPS (global positioning system) receiver where the X:Y coordinates were recorded on a mapping data sheet.

Observations were done on sampled streets focusing on the state of the roads using a ranking of 1-5 (adopted from the Indian roads coding system) and pothole characteristics such as shape, size and position. A digital camera was also used as an observation tool and

Table 1 Sampled streets in the different residential areas of Gweru.

Residential area	Sampled streets
Senga-Nehosho	Ziyambi Drive, Matongo Way, J Shava Road, Chiwaya Street and Senga Road
Kopje	Kopje Road, Strand Road, Princes Drive, George Avenue
Ridgemont	Hillcrest Road, Umsungwe Road, Grays Road
Mkoba 6 and 7	Mkoba Road, Paradza Road, Chilimanzi Road, Hamutyineyi Road, Makoni Street
Lundi Park	Lundi Road, Malvern Avenue, St Annes Drive, Coughlan Avenue
Ivene	Murifield Avenue, Rosemere Street, Gulane Road, Turnberry, Rivermead Road

some images were taken to give a vivid illustration of the state of the roads.

3. Results and Discussion

3.1 Senga and Nehosho High Density Residential Areas

A total of 47 potholes were analysed on sampled roads in Senga and Nehosho residential areas. A stretch of about 11 m × 6 m at the intersection of Ziyambi Drive and Matongo Way and a 20 m × 6 m stretch along Ziyambi Drive are now more of gravel than paved surfaces. 36% of the studied potholes were small (less than 150 cm in circumference), 34% were medium sized (151-300 cm in circumference) whilst 30% were large (more than 300 cm). Large potholes at some points such as at the intersection of Chiwaya Street and Senga Road have circumferences averaging 568 cm, diameter of 242 cm and 6.2 cm in depth covering almost the whole lane. The distribution of potholes recorded and measured on sampled streets in Senga and Nehosho high density areas is shown in Fig. 3.

Interviews held with some of the Senga-Nehosho commuter omnibus owners and the city engineer revealed that the city council once carried out pothole patching but the potholes resurfaced after a very short period of time. This was mainly because the city council lacks financial resources and therefore uses pit sand, the cheapest material available for patching up potholes. At the intersection of Ziyambi Drive and Matongo Way the road has become an almost completely gravel section with patches of tar remaining only on recently patched parts as shown in Fig. 4. Ziyambi Drive is the main road used by both public vehicle transporters and private cars getting into Senga and Nehosho suburbs. The high traffic volumes and the impact of turning vehicles at the intersection of Ziyambi Drive and Matongo Way have exacerbated pothole development particularly at the intersection. Poor drainage resulting in waterlogging, high traffic volumes, lack of timeous maintenance and poor construction standards have been cited as the main drivers of the high rate of pothole development in the Senga-Nehosho area.

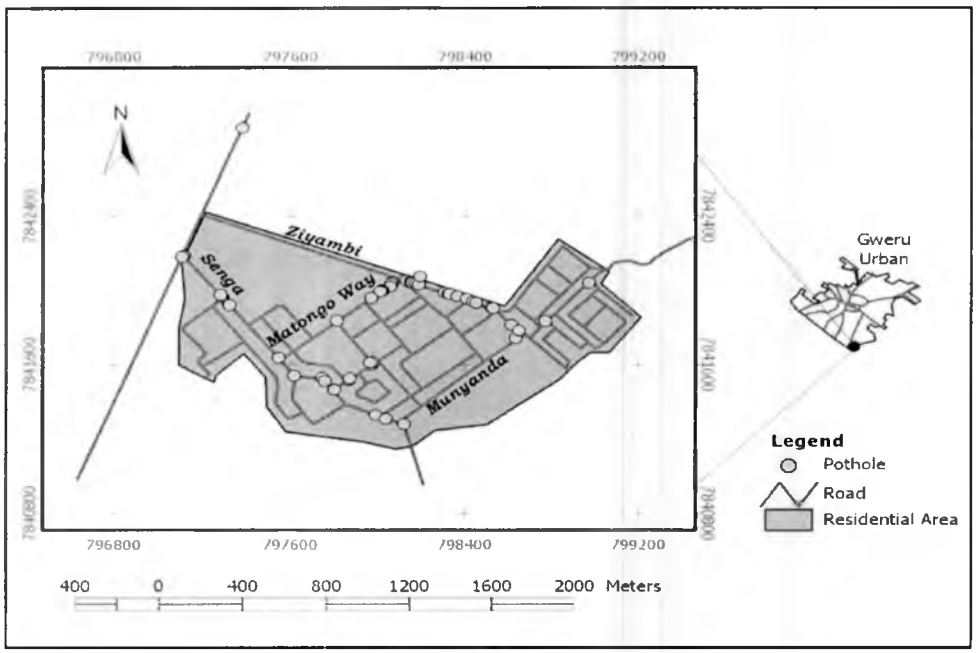

Fig. 3 Distribution of potholes on sampled streets in Senga-Nehosho residential area.

Fig. 4 State of the road at Ziyambi Drive and Matongo Way intersection in Senka-Nehosho area.

Ziyambi Drive is the most highly potholed road compared to other streets in the two suburbs as evidenced by the high pothole concentration per unit distance. Some potholes have merged along this road to form about 20 meters of continuous gravel stretches. Drivers and passengers also concurred that Ziyambi Drive leading to Nehosho and Senga road leading to Midlands State University have most potholes. This was because these are the major roads used by public transport into the suburbs. Damage is even worse at the corners and intersections of these busy roads. This was corroborated by direct observation. Senga road leading to Midlands State University however has the advantage of receiving frequent and thorough attention from the city council at the insistence of the university authorities who ply the road almost on a daily basis. This road is therefore generally in a moderate state when compared to Ziyambi Drive and others of similar utilization intensity. Matongo Way and Chiwaya Streets both also have fewer potholes because fewer commuter omnibuses and small vehicles ply these roads.

3.2 Mkoba 6 and 7 High Density Residential Area

There were about 17 potholes recorded on sampled roads in Mkoba 6/7. Patching work using pit sand had just been done on several roads at the time of study but Paradza Road linking Mkoba Road and Chilimanzi Road had not been patched despite clear evidence that the city council was through with maintenance work in the area. This was because the city council targeted major roads only. At the intersection of Chilimanzi and Hamutyinei Roads the formerly tarred surface is now just a gravel surface. Observations showed that the main cause of damage along these two roads were the construction trucks heavily loaded with sand, bricks and concrete to the recently established residential area where the housing construction business is booming. The Gweru city council roads engineer revealed that Hamutyinei Road was resealed in 2009, but with the high traffic volumes found along the route, potholes of various sizes are already a common feature and the demand for frequent maintenance is beyond the current capacity of the local authority. The city engineer felt that with the current challenges bedevilling the city council, Hamutyinei Road was in a good state despite the existence of occasional potholes. The main affected area in Mkoba 6 and 7 was the intersection of Paradza and Chilimanzi Roads where five potholes with circumferences above 301 cm were identified. These were mainly due to poor or lack of maintenance work done on Paradza Road. Fig. 5 shows the distribution of sampled potholes in villages 6 and 7 of Mkoba high density residential area.

3.3 Ridgemont Low Density Residential Area

Ridgemont, like other low density suburbs formerly meant for residents of European origin or decent, has generally moderate to low potholed roads. The main affected roads are Grays and Hillcrest. Hillcrest Road

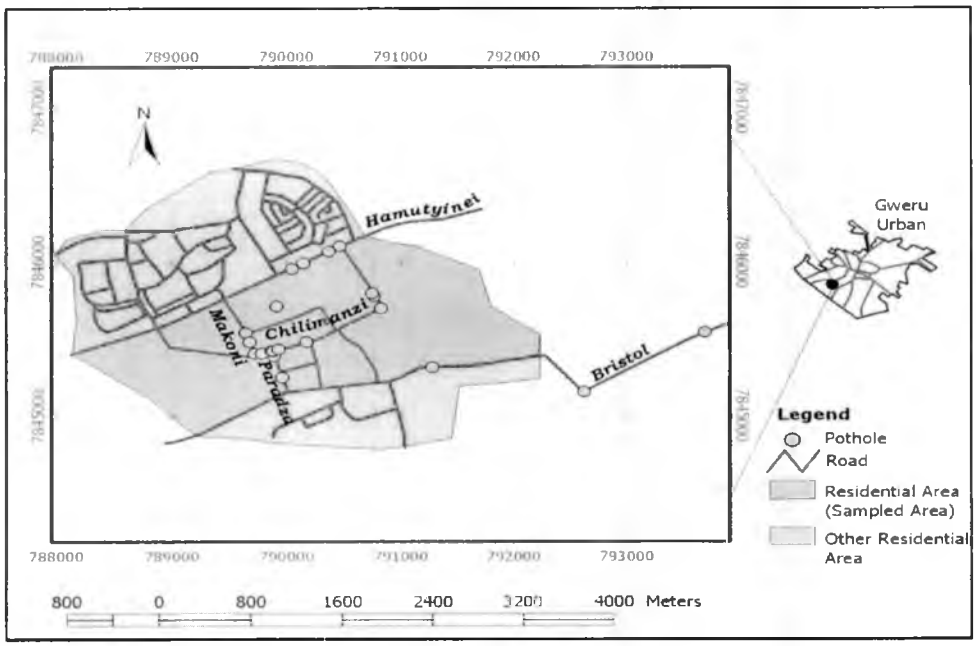

Fig. 5 Distribution of potholes on sampled streets in Mkoba 6 and 7.

has since been abandoned as it resembles a gravel road. There has been extensive soil filling on the road. Grays Road has eight potholes which are generally spaced. The biggest pothole recorded along this road measured about 510 cm in circumference, 236 cm in diameter and had a shallow depth of about 0.8 cm. Shallow depths indicate that Grays Road has a strong and thick surface and the tar surface is only giving in due to age, stress caused by tyre pressure and climatic variations. Although potholes in this area are few, majority of them are large (60%) whilst 40% are medium size. This implies that there has been little work done on maintenance recently as there is no much formation of new potholes but continued freaking of the already existing ones. The few potholes found on Grays Road can be attributed to the aging of the roads and little or no maintenance services by the city council. Ridgemont suburb roads are not frequently maintained because among other reasons. The suburb's residents are less influential politically as well as in council matters. Fig. 6 shows potholes on sampled roads in Ridgemont low density suburb.

3.4 Kopje Low Density Residential Suburb

This suburb has roads with the least amount of damage compared to all the other sampled residential areas. Among the four sampled roads only Strand Street had two large potholes with diameters of 212 cm and 186 cm, depths of 3.56 and 2.8 cm and circumferences of 528 cm and 394 cm, respectively. These potholes are a result of road weakening due to overgrown road side tree-roots prying laterally below the surface leading to the development of road surface cracks. The cracks promote water infiltration and are therefore both widened and deepened by vehicle movement forming the potholes that were observed. Kopje Road, George Avenue and Princess Street are in perfect condition despite their advanced ages. These roads have been resistant to weakening caused by water infiltration because they were constructed at a gradient that facilitate good drainage. In addition, the low density suburbs such as Kopje are homes to some of the most influential individuals in the city such as high ranking city fathers, political heavy weights and top business people. This results in streets in these

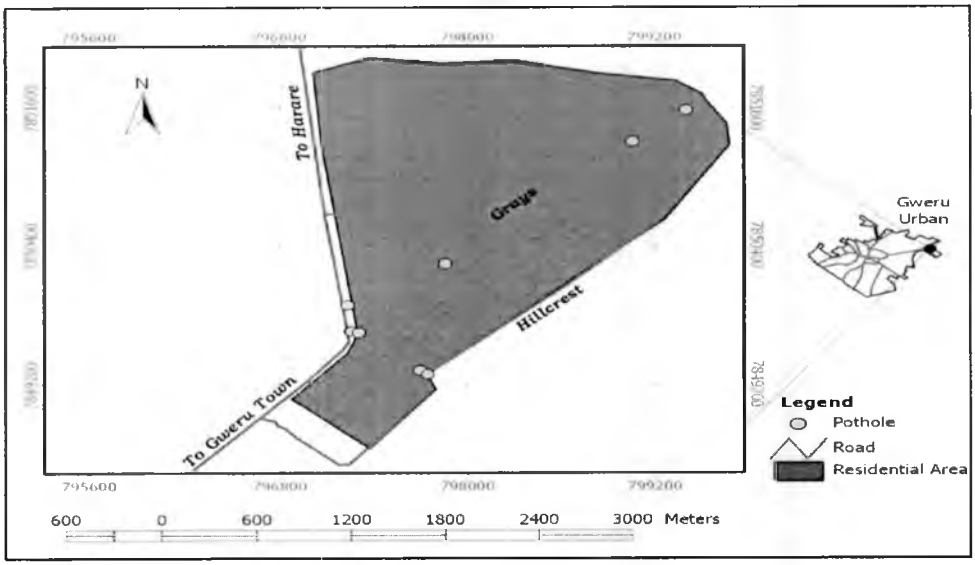

Fig. 6 Potholes on sampled streets in Ridgemont residential area.

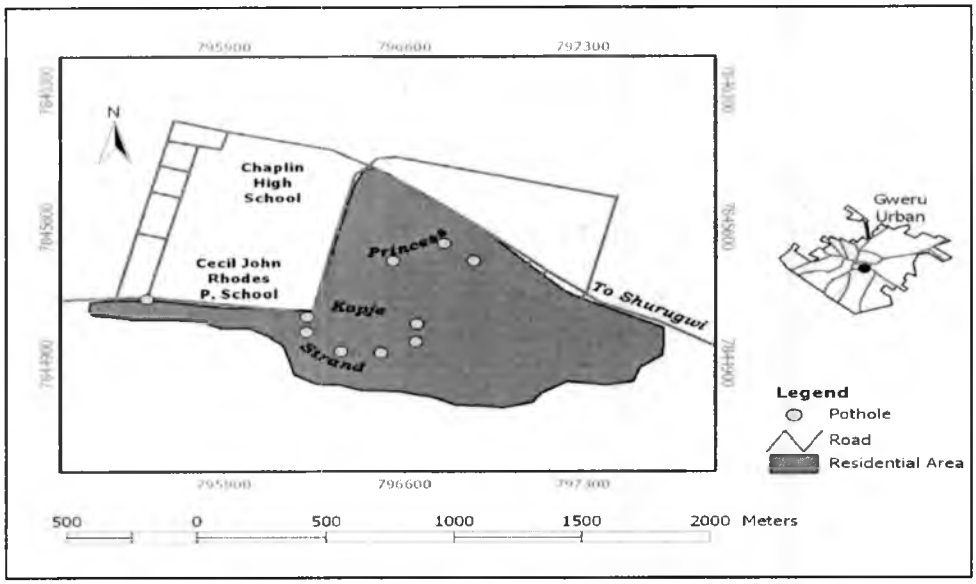

Fig. 7 Potholes on sampled streets in Kopje residential area.

suburbs receiving urgent attention whenever their conditions deteriorate. Some points where signs of surface freaking due to aging were evident were however recorded but they were not well developed to be a cause for concern. However, this is the stage at which maintenance should be done to neap the problem whilst it is still in the buck and keep both maintenance and vehicle damage low. Fig. 7 shows pothole positions in Kopje low density suburb.

3.5 Lundi Park Medium Density Residential Area

Lundi Park, a medium density residential area, had clear signs of negligence as far as road maintenance is concerned. The potholes in this residential area range from 66 cm to 337 cm in circumference, 25.3 cm to 168 cm in diameter and depths between 0.96 cm and 3.6 cm.

Most potholes are on Malvern Street where eight potholes were recorded and 83% of these were on the centre of the road with an average depth of 1.83 cm. 67% of the potholes were small, 17% were medium and 16% large in size.

The big proportion of the small potholes shows that there are higher rates of pothole formation associated with the rain season. The low gradient of the roads promotes the accumulation of water thereby weakening road surfaces that causes potholing of several sections. This is worsened by little or lack of timeous maintenance work to arrest further road deterioration in the residential areas. Fifteen potholes were recorded on the sampled streets in Lundi Park suburb as shown in Fig. 8.

3.6 Ivene Medium Density Residential Area

Of all the potholes that were recorded on sampled roads in Ivene residential area, 47% were large, 33% were medium and 20% were small. The largest pothole which resembles a wilderness ditch along Murifield Road has a circumference of 598 cm, depth of 8.7 cm and a diameter of 305 cm. This poor condition of roads in Ivene is a result of a combination of factors chief among them being aging, substandard construction, gentle gradient promoting water infiltration, weak unconsolidated sand soils that dominate the area and lack of maintenance. A stretch on Murifield Road leading to Ivene shops shown in Fig. 9 bears testimony to what commuter omnibus drivers and the suburb residents called "the suburb of the bumpy roads".

There is no doubt that by any standards, roads in this area are in a very dilapidated state with little patches of tarmac remaining behind predominantly gravel surfaces. Most commuter omnibus owners whose vehicles ply these routes complained of serious mechanical damage to vehicles warranting high frequency of repair services and raising the costs of the transport business in the area. In addition to the causes of poor road conditions in the area already stated, the roads in the area particularly Murified Road are frequented by heavy vehicles carrying construction sand further accelerating the rate of deterioration of the roads in the area. In the inner areas of the suburb, commuter omnibuses are the main vehicle traffic. These have also caused their own fare share of damage along Turnberry, Rosemere and Gulane roads as evidenced by the presence of some long elongated

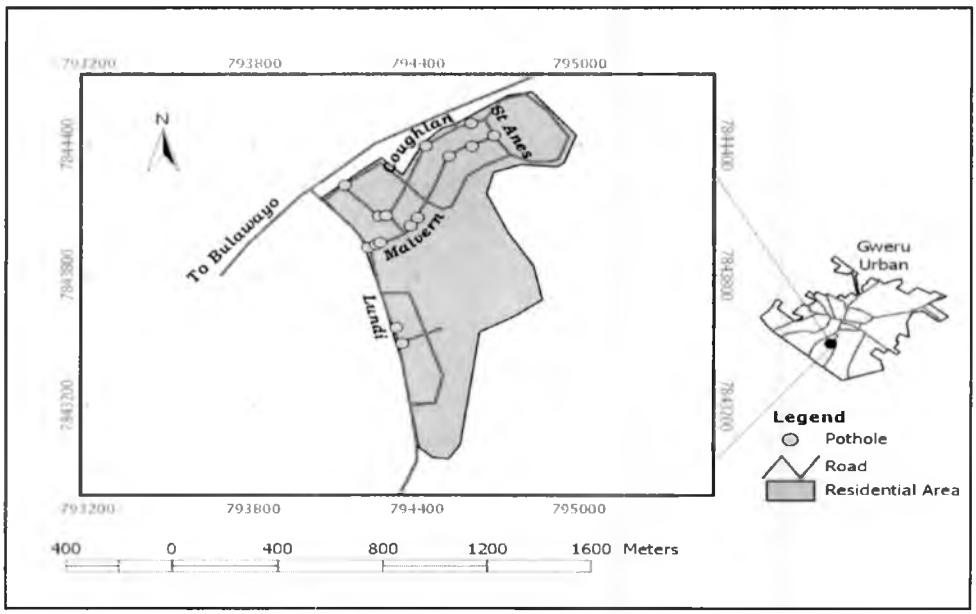

Fig. 8 Potholes on sampled streets in Lundi Park residential area.

Fig. 9 Aged and neglected Murifield road strip in Ivene residential area.

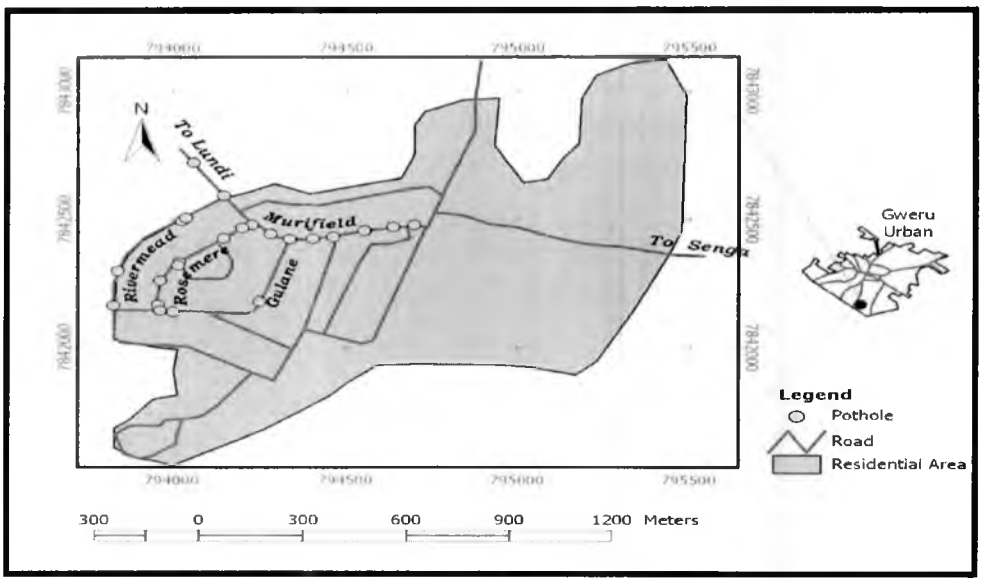

Fig. 10 Potholes on the sampled streets in Ivene residential area.

potholes along these inner suburb roads. The recorded potholes are shown on the street map of Ivene in Fig. 10.

4. Rate of Pothole Existence on Sampled Roads

There are higher rates of pothole formation in the high density residential areas as compared to low density residential areas. In fact, the potholes follow the population density trend in the residential areas of Gweru. High density residential areas have the highest rates of pothole formation per unit distance, followed by medium density suburbs and lastly low density suburbs of Kopje and Ridgemont as shown in Fig. 11. This tallies with the city roads engineer's survey results in which she highlighted that the roads in high density residential areas are more prone to pothole development due to the low cost surfacing applied as

tar surfacing is expensive. The Gweru City Council Roads engineer cited the economic meltdown that Zimbabwe experienced between 2000 and 2009 as the main contributing factor towards lack of an effective road maintenance programme during this period since this chronically incapacitated the local authority to carryout maintenance work on the already poor road network particularly in high density residential areas.

Traffic volumes in high density roads have substantially increased due to the introduction of the 12 to 35 seater commuter omnibuses since the 1990s as compared to the 65 to 75 seater Zimbabwe United Passenger Company (ZUPCO) big buses. The big buses had their fare share of challenges with regards to residential areas' road conditions due to their size, significantly damaged particularly weakly constructed high density suburban roads. The high commuter omnibus traffic volumes have further weakened the substandardly constructed and aged tar surface causing potholes development. The potholes are further enlarged during wet periods since they are collection points for rain water leading to the peeling off of asphalt due to tyre pressure.

However, maintenance work was resumed on some roads after the adoption by the government of the multi-currency system in 2009. The liquidity crises combined with political bickering between the former opposition MDC party-led Gweru City Council and the ZANU PF-led Ministry of Local Government and Urban Development has seen service delivery including road maintenance progressing at a snail's pace and mostly employing ineffective methods and materials such as pothole patching with gravel which is easily washed away by running water. The areas that have benefitted from these temporary measures include Senga mainly the City-Senga-MSU road, some areas in Mkoba as well as areas around the city centre. The medium density residential areas of Ivene and Lundi Park are yet to have their dilapidated road surfaces attended to. Standard surfacing done in low density residential areas such as Kopje during the colonial period is still intact. The roads in low density residential areas were properly constructed during the colonial era to ensure that the residents enjoy quality urban life such as roads among other services.

The pothole formation rates per kilometre in the sampled suburbs are shown in Fig. 11.

5. Socio-Economic Impacts of Potholes

From the interview carried out with the Gweru City Council Roads engineer, potholes remain a perennial problem as road construction and/or maintenance is

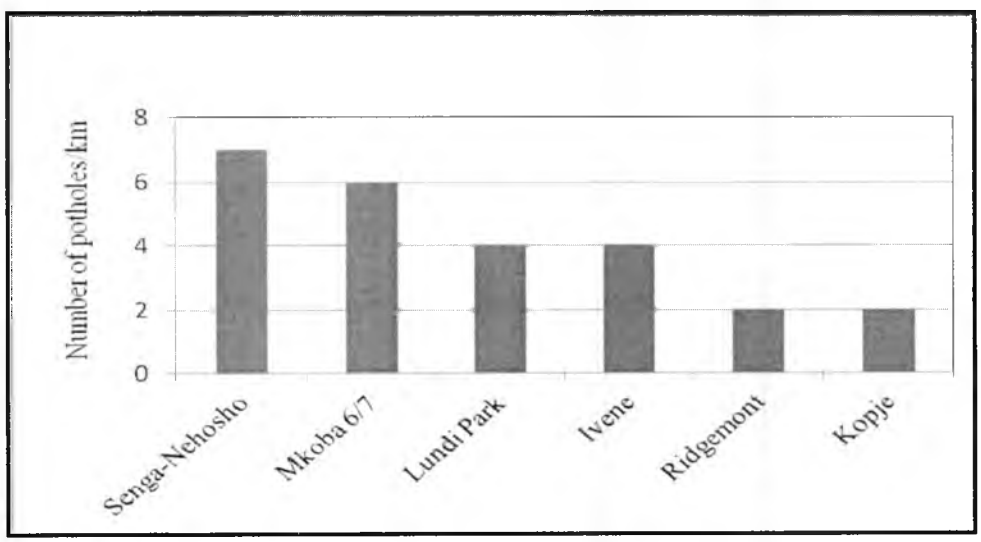

Fig. 11 Number of potholes found on sampled roads per kilometre in residential area.

very costly and worse still the council lacks its own road maintenance equipment and plant. Hiring of road maintenance equipment is costly and therefore pothole repair at most times is not done up to standard. There is need for proper compaction using the right type of materials for the potholes to be completely sealed but the Council lacks both appropriate equipment and road surfacing materials leading to manual compaction using hand-held tools and soil which is ineffective and short lived. About 70% of the money allocated to the road construction and maintenance budget is spent on hiring equipment and thus very little money is left to cover all areas of need. To solve the problem, the city council resorts to pothole patching, resealing, and overlaying.

Commuter minibus drivers, like other motorists and the travelling public, seriously complained about the challenges faced when driving on potholed roads. One can hardly drive without occasionally swerving to avoid the potholes. "I have to meander to find my way in a pothole-damaged road to minimise the huge expenses incurred after hitting potholes", one driver stated. In many instances, an entire lane could be full of these potholes which are almost unavoidable at night and when it is raining.

Some of the impacts of potholes on the commuter minibus owners operating in the studied areas are summarised in Table 2.

Potholes affect vehicle operating costs particularly the costs associated with maintenance, tyres and fuel. Roads in poor condition result in higher variable costs of operation because they reduce fuel efficiency, damage vehicles leading to higher maintenance and higher operation costs, reduce the life of tyres, reduce vehicle utilisation due to lower speeds and reduce the life of the truck [14]. In the studied areas, commuter minibus operators experienced all the variable costs, that is, high fuel consumption, frequent maintenance, tyre damage notably frequent punctures, reduced business due to low speeds and complete vehicle breakdown beyond repair over short operating life span particularly operators plying high density residential area routes such as in Senga-Nehosho and Mkoba.

Vehicle mechanics concurred that most cars develop suspension defects since most vehicles are not designed to deal with the sharp and repeated shocks caused by potholes. One of the mechanics interviewed stated that pothole-related vehicle damages are rampant especially in the wet season as most potholes form during this time and drivers hit them unaware as they will be concealed under flood waters. Furthermore, pothole induced vehicle mechanical faults and the general poor state of roads increase the risks of accidents and loss of life costing individuals, families, companies and the government valuable financial, human and other material resources for the much needed development activities. With respect to suspension problems, interviewed vehicle mechanics stated that they can not be fixed in any other way besides through replacement which requires more

Table 2 Mechanical and economic impacts of potholes to commuter owners by route operated.

Area	Spare parts replacement	Repairs	Tickets/fines	Vehicle impoundments	Other impacts
Senga-Nehosho	Suspension, ball joints, tyre once in every 4 months	Bent rims, tyre punctures	At least 5 a month/vehicle, may receive more during public holidays		High fuel consumption rates, engines not fuel efficient
Mkoba 6/7	Tyres, ball joints, suspension	Tyre puncture, bent rims	At least 3 a month/vehicle	2 vehicles for three weeks-not road worth	High fuel consumption, expensive servicing monthly
Ridgemont		Tyre punctures	At least 1 a month/vehicle		Car parts mostly imported becoming costly to service the vehicles
Ivene/Lundi Park	Tyres, ball joints	Tyre punctures		1, no recent safety review document	

money and labour than other technical problems.

Some commuter minibus drivers and vehicle owners pointed out strategies they have adopted to minimise the huge expenses incurred after hitting potholes. Preventive maintenance is delayed or in some cases skipped altogether. For those operating older vehicle models with simpler technology, the vehicle owners and/or drivers tinker with their engines and improvise repairs and parts to lower maintenance costs and challenges of replacement parts shortage and unavailability. This entails servicing or repairing the vehicle at the backyard or on the road side instead of taking them to garages with trained mechanics. Most commuter minibus crews indicated that trouble shooting skills are paramount and every member has to have them since the vehicle can just "cease" on the middle of the road after hitting a pothole. This necessitates along the road repair work to enable business to continue. It is only the problems they would have failed to address that are referred to specialists. With regards to tyres, the tendency is to resort to cheaper low quality second hand tyres and retreaded ones. To reduce fuel consumption, some drivers stated that they engage the neutral gear and switch off the engine on steep sections of the road, allowing the gained momentum and gradient to drive the vehicle for the entire extent of the steep reach.

Potholes have also been reported to cause ball joint, rims and tyre damage as well as mis-alignment of wheels and engine malfunctioning. Most commuter omnibus drivers complained that the problem of wheel alignment and suspension problems compromise their driving as it affects steering control. Furthermore, when the drivers dodge the potholes, the police accuse them of careless driving and fine them on the spot. The penalties are paid for by the vehicle owners straining the employer-employee relations.

During the hyper-inflationary and economic collapse period of 2000-2009 some vehicle owners operating in high and medium density suburbs such as Ivene/Lundi, Mkoba and Senga ceased operations as vehicle repair parts such as ball joints, tyres and rims were both unaffordable and unavailable on the local market. Unroad-worthy vehicles impounding by the VID (Vehicle Inspection Department) has also compounded vehicle owners' problems as they have to pay a fine or a bribe and thereafter incur repair costs. Though Commuter Owners Association representatives hold periodic meetings with the Gweru City Council authorities pertaining to road conditions among other issues, there have been slight improvements as potholes continue to resurface and mostly in the same areas and positions. Some commuters however applauded the effect of potholes on speed since commuter omnibus drivers have a tendency of speeding even in residential areas risking running over children that always use roads as playgrounds.

Passengers experience their own share of problems caused by bumpy potholed roads. They complain of unexpected "earthquake" bumps when they are onboard the commuter vehicles and private cars. Others have had the devastating effects of getting maimed and losing their loved ones in accidents caused by the bad state of the roads in which drivers encroach into another lane to avoid potholes. The pothole problem therefore needs real attention if development and socio-economic benefits are to be drawn by all sectors of society.

6. Conclusion and Recommendations

Problems of funding from the central government have led to poor infrastructure development and maintenance especially in some high density residential areas such as Senga-Nehosho and Mkoba 6/7. The roads in Senga-Nehosho, Mkoba and Ivene are in a bad state causing real threats to road users' safety as some have become worse than rural unmaintained gravel roads. A combination of low cost surfacing, poor drainage and high public transport vehicle volumes make high density areas' road network more prone to pothole formation than low density areas. The

pothole frequency per unit distance increases from low density suburbs to high density areas and therefore high density areas have roads in poorest condition compared to medium and low density areas. The way in which road maintenance is being carried out by the city authorities lives a lot to be desired. The measures being taken to address road infrastructure challenges are piecemeal, limited in scope and very temporary in character making the efforts costly to the local authority itself, transport operators and the commuting public. Mostly, repairs are substandardly done during the rain season exposing the seal to strain and lasting only a few weeks if the rains are strong. The city council must note that patching is no longer the solution, most roads especially in the high density areas need complete rehabilitation since they were allowed to deteriorate for too long. There appears also to be selective maintenance of the roads with those in low density areas receiving more attention than those in high density areas making the pothole problem more of a low class perennial problem as compared to the upper class who reside in low density residential areas.

Given the prevalence of potholes on Gweru roads particularly in high density areas, there is need for council to put notices on roads signalling drivers to slow down in pothole areas. Some heavily depleted roads like Murifield Road in Ivene and some parts of Ziyambi Drive in Senga-Nehosho have gone past their lifespan and need complete resurfacing. Roads in high density residential areas should be continually monitored against pothole development as they accommodate high traffic volumes. This is especially necessary given the fact that more than 70% of the city's population reside in high density suburbs and mostly use small commuter omnibuses which ply the roads continuously on a daily basis. Safety of citizens on the roads should therefore be prioritised by the city council. The City Council should make continuous surveys of roads to determine their state. City Council workers should timely report any potholes forming in their places of residence as they can monitor the roads daily to and from work. Council should also work with telecommunication companies and establish toll free lines for road users to report potholes directly to the council as and when they form. This will ensure timeous attention to the potholes and reduce continuous tarmac surface depletion.

There should be equal surfacing for all residential areas and even better surfacing in high density areas as there are higher traffic volumes warranting frequent and stronger surfacing. There is also need for the local authority to foster partnerships with private organisations in road maintenance and the provision of other services since going it alone has proved to be an insurmountable challenge. Local business operators and industrialists are encouraged to adopt specific roads/streets as part of their cooperate responsibility so as to assist in road infrastructure development and maintenance. Seasonal recruitment of road maintenance workers especially during the wet season may be helpful in reducing pothole development. Council must diversify its revenue base by embarking on fund raising projects so as to buy road maintenance equipment which it desperately needs for both road development and maintenance.

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