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A Paradigm Shift in Geometric Design of Low Volume Rural Roads

Authors:

J. Hongve
Independent Consultant
Ostveien 645
3145 Tjome
Norway
E-mail: joho@operamail.com

Ilho#rgh#Fkdqjhg

M.I. Pinard
Infra Africa (Pty) Ltd
Private Bag 00426
Gaborone
Botswana
E-mail: mipinard@global.bw

Ilho#rgh#Fkdqjhg

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Acronyms and Abbreviations

SSA	Sub-Saharan Africa
LVR(s)	Low Volume Road(s)
Vpd	vehicles per day
Km	kilometre
RTI	Rural Transport Infrastructure
Km/h	Vehicle speed in kilometres per hour
NMT	Non-motorised traffic
ORN 6	Overseas Road Note 6
DC	Design Class
M	metre
ADT	Average Daily Traffic
AADT	Annual Average Daily Traffic
PCM	Perceptual countermeasures
RSE	Road Safety Education

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Abstract

It is widely recognized that provision of basic road infrastructure is a key factor for economic growth and poverty reduction in the rural areas of Africa. Recent (2013) estimates by the World Bank indicate that approximately 63% of the total population of Sub-Saharan Africa (SSA), equating to more than 500 million people, are located in rural areas with only 34% living within two kilometres of an all-season road. Moreover, if SSA agricultural potential is to be realised, the size of the rural road network would need to be increased by a factor of about 5 – 6 times. Much of this increase would be in the form of low volume roads (LVRs) with traffic volumes typically up to about 300 vehicles per day (vpd).

With the limited resources that are available for provision of LVRs, it is crucially important that appropriate and affordable geometric design standards are adopted. However, it appears that little research has been carried out to develop standards for roads that essentially fulfil an access function, with acceptable levels of service, at least cost and to as many rural communities as possible. Indeed, current standards tend to follow conventional practice based on the design speed concept, resulting in levels of service that are often far in excess of what can be economically justified or is necessary for the provision of basic access.

The purpose of this paper is to promote the adoption of a more appropriate geometric design philosophy for LVRs that is rational and more affordable than hitherto, and with acceptable levels of road safety in what is a generally low speed environment.

The paper briefly reviews current approaches to geometric design of LVRs and highlights their shortcomings as a basis for motivating a case for the adoption of more appropriate and affordable standards, including road safety measures. The paper concludes that unless there is a paradigm shift in the approach to geometric design of LVRs that is embraced by engineers and practitioners and manifested in government policy, the rural population in Africa will be denied their human rights and opportunities for social and economic development.

1. Introduction

1.1 Background

The sustainable provision of road infrastructure to rural communities in Africa is essential for their livelihoods and may be viewed as a universal human right in terms of facilitating poverty reduction, food security, access to markets, healthcare, education and social and economic opportunities of every kind.

In 2013 the rural population in Sub-Saharan Africa (SSA) was estimated by the World Bank to be approximately 63% of the total population of the region, equating to more than 500 million people. This population is served by a vast network of rural roads of which the majority are in poor condition and largely un-trafficable in the wet season. In 1991 the network was estimated to approximately 700,000 km[1] [1]. However, if the agricultural potential of the region is to be realised it has been suggested that this figure would need to be increased up to tenfold [2]. On this basis it can safely be assumed that the length of current existing rural road network is approximately 1 million km and that a further 5-6 million km would be required, mostly in the form of low volume roads (LVR), to adequately serve the rural population and sustain socioeconomic development.

Adding to the challenge of sustainable provision of rural roads is the effect of global climate change with increased precipitation and temperatures, which are likely to accelerate the deterioration of the road network in the years to come. In most of the SSA countries, almost the entire rural road network is unsurfaced and is therefore particularly vulnerable to increased rainfall, which is forecast to affect large parts of the SSA region [3].

SSA governments' ability to provide and maintain rural transport infrastructure (RTI) is severely limited by resources. It is therefore crucially important that appropriate and affordable geometric design standards are adopted with due attention to road safety.

[1] This figure comprises public roads functionally classified below Primary, Trunk or Secondary roads and includes roads described as Rural Access, Feeder, Agricultural, Irrigation, Forestry or Unclassified roads and may include Tertiary roads where these are functionally grouped as Rural Roads as defined here.

Accordingly, the prime considerations in defining rural road improvements should be reliability and durability rather than width and sped. ***Affordability*** thus becomes the key criterion for decisions on standards. This would lead to concentrating expenditure on essential access, rather than on geometric characteristics determined by design speeds [1, 4, 5].

1.2 Purpose and Scope

The purpose of this paper is to advocate for a paradigm shift in the philosophy and principles for geometric design of LVRs. Whilst significant advances have been made in pavement design for more cost efficient provision of such roads, geometric design standards and guidelines are still, for the most part, based on traditional concepts developed for rural highways, i.e. for roads with relatively high design and operating speeds and levels of service. The paper briefly reviews current approaches to geometric design of LVRs and motivates a case for the adoption of more appropriate and affordable standards coupled with cost effective road safety measures based on international research findings. Design elements such as curve radii, super-elevation, k-values etc. are well established and can be adopted from existing design manuals to the extent that these aspects are relevant. These issues will therefore not be dealt with here.

1.3 Methodology

Information gathered from an extensive international literature search on past research on Low Volume Rural Roads and associated Rural Road Safety was assessed against geometric design standards from two randomly selected design manuals in the region. Most of the research has been done on rural roads in a relatively high speed environment and it was found that there is an information gap on typical LVR with less than 300 vdp, particularly regarding road safety and accident statistics. Practical considerations and personal field observations were used together with potentially cost-effective traffic safety measures to arrive at general recommendations for affordable LVR geometric standards.

2. Geometric design

2.1 Definition and Characteristics of a LVR

Rural roads comprise roads with widely different characteristics in terms of function and service level. In the following a distinction is therefore made between roads with:

- **A mobility function** – defined as uninterrupted all-year, high quality (high speed, low roughness) access), and those with
- **A basic access function** – defined as reliable all-season access for the prevailing means of transport with limited periods of inaccessibility.

Roads with a mobility function require relatively consistent cross section and design speed throughout the alignment and should be designed in accordance with conventional highway design principles.

In this paper the focus is on the geometric design requirements for LVRs with a basic access function, defined as follows:

- Roads carrying up to about 300 vpd (projected at middle of design period) with a low proportion of heavy, commercial traffic (typically < 20%).
- The road is unlikely to change its function over its design life.

Other characteristics of LVRs that have a bearing on their geometric design include:

- A need to cater for a significant amount of NMT, motorcycles and bajajs, which engenders a need to adequately address road safety.
- Variable travelling speeds normally in the range of 30 – 60 km/h and seldom exceeding 80 km/h, as dictated by the local topography.

2.2 Design principles

Geometric design is the process whereby the layout of the road through the terrain is designed to meet the needs of all the road users. However, the needs of road users on LVRs are quite different from road users on mobility roads as defined above. Accordingly, the standards and levels of service on basic access roads are generally lower than on mobility roads. Such standards are intended to meet two important objectives, namely: to provide a minimum level of service as well as an acceptable level of safety and comfort for all road users.

The geometric design process is a complex task and goes beyond merely applying values extracted from a table of standards. Every road is a unique undertaking which is never precisely repeated. There are only limited "off-the-shelf" solutions to situations encountered in practice, and the unthinking application of charts, tables and figures is unlikely to lead to a successful design outcome. Good design requires creative input based on a sound understanding of the principles involved.

In principle, a geometric standard represents a service level that is deemed appropriate for the particular road environment. Typically, this service level increases with traffic and is relatively high for major, highly trafficked roads and has a clear connection with transport efficiency and economic benefits. For LVRs the benefits of a high service level are less tangible in economic terms and, as a result, a compromise has to be reached between service level and costs. Thus, in order to produce an economic standard, a balance needs to be struck between the cost of improving the alignment, both horizontally and vertically, and the benefits to be derived from so doing – an approach that emphasizes the economic aspects of geometric design which needs to be applied with appropriate understanding of economics and flexibility.

2.3 Review of Current Geometric Design Standards

Most of the research on rural roads in developing countries, on which current design standards and recommendations are based, was carried out in the late 1900s [6]. The research focused largely on rural roads in general and the designs were based on the traditional concept of "design speed". Very little research appears to have been done *specifically* on the requirements for LVRs, although some valuable research dating back to the 1960's [7] was carried out. However, the problem seems to be that this research is largely forgotten and that engineers of yesterday and today are trained in conventional highway engineering technology. University courses dealing with the particular requirements for LVRs building on this research simply do not exist.

Overseas Road Note 6 [8], which has been a key reference document for design of rural roads since it was first issued in 1988, was largely based on research carried out in the 1980s [6]. This and subsequently developed national design guidelines [9, 10] are all based on the concept of design speed for setting of geometric design standards.

Tables 1 to 3 below shows the recommended geometric design standards in ORN 6 and two recently developed geometric design manuals. From these tables it is evident that despite urgent need for expansion and improvement of the SSA rural road network identified above and the call by the World Bank [1, 3] for concentrating investments on LVRs on satisfying basic access requirements, the development of geometric standards has gone in the opposite direction from the relatively modest standards proposed in ORN 6, particularly for the highest classes of LVRs (Class D in ORN 6, Class DC 5-7 in Table 2 and DC 4 & 3 in Table 3)

Table 1: Road Standards as defined in Overseas Road Note 6 (LVR design classes D – F)

Road function			Design class	Traffic ADT	Surface type	Width (m)		Max gradient	Terrain / Design speed (km/h)		
						C/way	Shoulder	%	Mount.	Rolling	Level
Arterial			A	5,000-15,000	Paved	6.5	2.5	8	85	100	120
Arterial			B	1,000-5,000	Paved	6.5	1.0	8	70	85	100
Arterial	Collect		C	400-1,000	Paved	5.5	1.0	10	60	70	85
	Collect	Access	D	100-400	Paved/Unpaved	5.0	1.0	10	50	60	70
		Access	E	20-100	Paved/Unpaved	3.0	1.5	15	40	50	60
		Access	F	0-20	Paved/Unpaved	2.5/3.0	Passing places	15/20	n/a	n/a	n/a

Table 2: Example from a typical Road Geometric Design Manual (LVR design classes DC5-DC8)

Road function			Design class	Traffic ADT	Surface type	Width (m)		Max gradient	Terrain / Recommended Design speed (km/h)		
						C/way	Shoulder	%	Mount.	Rolling	Flat
Trunk/Regional			DC 1	> 8,000	Paved	2 x 7.0	2 x 2.5	Not specified	70	90	120
Trunk/Regional			DC 2	4,000-8,000	Paved	7.5	2.0	Not specified	60	80	110
Trunk/Regional			DC 3	1,000-4,000	Paved	7.0	2.0	Not specified	60	80	110
Trunk/Regional	Collector		DC 4	400-1,000	Paved	6.5	1.5	Not specified	50	70	100
Trunk/Regional	Collector		DC 5	200-400	Paved	6.5	1.0	Not specified	40	50	80
	Collector	Feeder/Local	DC 6	50-100	Paved/Gravel	6.0	1.0	Not specified	40	50	80
	Collector	Feeder/Local	DC 7	20-50	Gravel	5.5	1.0	Not specified	40	50	70
		Feeder/Local	DC 8	< 20	Earth/Gravel	4.0	1.0	Not specified	40	50	60

Table 3: Example from a typical LVR Geometric Design Manual (LVR design classes DC4-DC1)

Road function			Design class	Traffic ADT	Surface type[1]	Width (m)[2]		Max gradient	Terrain / Recommended Design speed (km/h)		
						C/way	Shoulder	%	Mount.	Rolling	Flat
Interstate/State			DC 8	> 10,000	High Volume Roads Refer to Geometric Design Manual						
Interstate/State			DC 7	3,000-10,000							
Interstate/State			DC 6	1,000-3,000							
Interstate/State			DC 5	300-1,000							
	County		DC 4	150-300	Paved	6.5	1.25/0.5	7/10/12	50	60	70
	County		DC 3	75-150	Paved	6.0	1.0/0.5	7/10/12	50	60	70
	County		DC 2	25-75	Paved	3.3	1.5/1.0	7/10/12	40	50	60
		Local	DC 1	< 25	Earth/Gravel	4.5	n/a	12	30	40	50
		Local	Track						n/a	n/a	n/a

1) Unpaved standards for DC4, DC3 and DC2 not shown. 2) Figures show values for Flat and Rolling / Mountainous

Presumably this trend in development of standards is based on road safety concerns, but these overly-generous standards cannot be justified neither for economic nor for road safety reasons, a view that is strengthened by the following quote (Boyce, McDonald, Pearce & Robinson, 1988):

"*Oglesby and Altenhofen (1969) found accidents to be rare on low-volume rural roads. Furthermore, there was almost no evidence to indicate that higher standards of formation width or surface type would reduce the already small number, **although they found that highway engineers appeared to believe the opposite**. From an economic standpoint, accident costs were found to be of a lower order of magnitude than construction and operating costs*".

2.4 Characteristics of LVR affecting geometric design

The particular characteristics of LVRs affecting the geometric design include [14]:

- LVRs often need to cater for high proportions of NMT including pedestrians, bicycles and animal drawn carts as well as motorcycle traffic, which during the last 10 years or so has grown tremendously in many parts of SSA and often constitute the main means of public transport.
- The majority of LVRs are relatively short in length and travel time would therefore most often not be a deciding factor for the required service level and associated geometric standard.

- Existing land use and adjacent properties often limit the effective cross section width that can be constructed without major disturbances for the local population and associated costs for land acquisition and compensations.
- Most road users are familiar with the terrain and alignment of the road and will therefore take necessary precautions to avoid conflicts and accidents.
- LVRs are often constructed by labour-based methods, which limits the amount of earthworks that can be done within reasonable costs.

2.5 Design Considerations

In light of the above LVR characteristics, the main concerns of the engineer are:

- To design a road that is "fit for purpose" by fitting the road into the physical environment at least cost allowing ***the existing alignment to fix the travel speed*** and ***variable cross section width to accommodate the prevailing traffic***.
- To address potential "black spots" with properly engineered solutions such as appropriate traffic calming or road widening and lane segregation at blind crest curves.

The adoption of these design principles will require some good engineering judgement to be exercised by the design engineer, hence the need for highway engineers to be re-oriented towards sound LVR engineering practices.

In the rare cases entirely new roads will be constructed, these are likely to be of a higher class justifying conventional geometric design, although elements of the LVR design principles could still be applied. For new LVRs the engineer will be faced with the same challenges as for existing roads and should design the road to be **fit for purpose** and **at least cost** as promoted in this paper.

2.6 Selecting the appropriate road width

A previous study on LVRs [10] has shown that a road with a daily traffic volume of 10 will produce about 0.05 conflicts per day per km assuming a speed of 40 km/h, and that this will increase to 1.3 conflicts per day per km if the daily traffic volume is 50. It is clear from these simple calculations that, particularly for the very low volume roads, a single lane road is all that is required i.e. with a running width of about 3.0 - 3.5 metres, with some provision for passing.

The formula for calculating the average number of conflicts is as follows:

$$\text{Conflicts/km/hr} = \text{AADT}^2/\text{Speed}/50/16$$

assuming AADT distributed over 16 hours.

Tables 4 and 5 show that even on roads with up to 300 vpd the number of conflicts/km/hr are very low and that considerable periods of time pass between potentially hazardous meeting situations.

Table 4: Average Daily and Hourly number of Conflicts / km

AADT	300		100	
Speed	Avg. Conflicts/km		Avg. Conflicts/km	
(km/h)	Per Day*	Per Hour	Per Day*	Per Hour
40	45	2,8	5,0	0,3
60	30	1,9	3,3	0,2
80	22,5	1,4	2,5	0,2

Table 5: Average time in between Conflicts / km

AADT	300	100
Speed (km/h)	Avg. time between conflicts / km	Avg. time between conflicts / km
40	21 min	3 hr 12 min
60	32 min	4 hr 48 min
80	43 min	6 hr 24 min

Moreover, on these roads vehicles tend to travel toward the centre of the road even with a road width of 6.0 m, which theoretically allows for lane segregated traffic. With this width, the outer wheel path is usually not clearly defined, but will typically be ≥ 1.0 m from the edge.

Thus, it can be concluded that for most of the time LVRs at all traffic levels as defined above are effectively operating as single-lane roads and that this feature can be used to ensure satisfactory levels of service and safety for all road users without resorting to inappropriate and unsustainable standards. A consequence of this is that shoulders in the normal sense or additional width to accommodate NMT in a low speed environment, can be omitted except in particularly busy areas within villages, trading areas etc. This would lead to substantially reduced costs compared to current LVR standards as shown in Table 2 and 3. Instead, other means of segregating motorised and NMT can be used, including innovative methods for road marking as discussed below or separate walkways where space is available.

Widening existing roads to construct shoulders is expensive and costs per m^2 for this additional width would in many cases be substantially higher than for the carriageway itself, all depending on the terrain, ground conditions and adjacent land use, and can therefore not be justified for LVRs.

Low volume rural roads abound in the developed countries as well, although often with traffic levels many times the maximum 300 vpd as per the LVR definition. Even so, authorities in relatively rich countries have found it unaffordable to widen and improve the alignments of these roads that often follow the alignment of old farm boundaries and natural topographic features. An example of a typical low volume rural road in Norway with AADT 2000, on an unimproved alignment, width of 5.50 m and speed limits varying from 40 to 60 km/h, is shown in Figure 1 below.

Figure 1: Low volume rural road in Norway, 5.50 m wide with AADT 2000

2.7 Accommodation of motorcycles

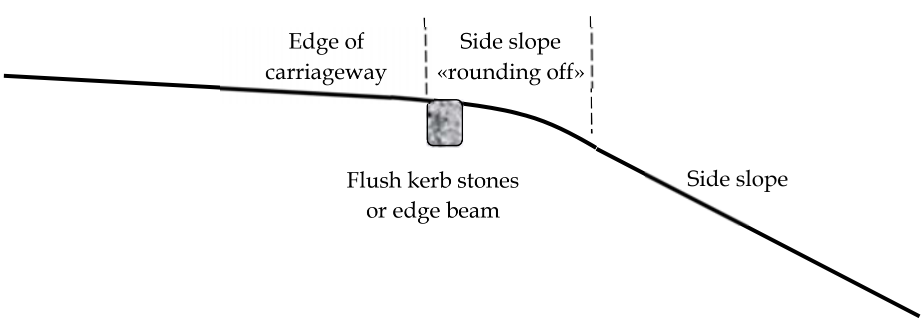
The high incidence of motorcycle traffic, which can only be expected to increase sharply in the future, will necessitate special considerations in terms of road width on LVRs. Motorcycles often travel at higher speeds than 4-wheeled traffic, even when speed reducing measures are in place, and drivers and passengers are often completely unprotected. Some additional width than strictly required for access may therefore be justified on the lower LVR classes to avoid hazardous conflicts between cars and motorcycles.

2.8 Edge protection on paved roads

With the omission of shoulders as proposed above, the lateral support to the carriageway and edge protection must be provided by other means. In older designs this was often provided very effectively by means of flush curb stones, but in recent times it appears that this feature is seldom considered. In rural areas it is sometimes impossible to determine at design stage the exact locations where traffic will drive off the road and eventually cause severe edge breaks and restrictions on the effective road width. If not rectified in time, edge breaks will be both a structural problem and a serious traffic hazard.

Engineers should therefore consider selective construction of edge lining as illustrated below in their designs.

Figure 2: Edge lining to prevent edge breaks



2.9 Design and operating speed

Design speed is traditionally used in highway design as an index which links road function, traffic flow and terrain to the design parameters of sight distance and curvature to ensure that a driver is presented with a reasonably consistent speed environment.

The design speed concept should be reconsidered as a basis for design of LVR for two reasons:

- LVRs are distinctly different from mobility roads, for which higher and consistent design and operating speeds may be justified.
- Applying design speeds to LVR designs to obtain a consistent speed environment will inevitably lead to increased earthworks, acquisition of adjacent land and properties for adjustment or horizontal and vertical alignment, and consequently unjustified project costs.

Operating speed on LVRs will therefore normally be variable and dictated by the terrain, existing alignment (in case of upgrading) and roadside developments. Normally LVRs will accommodate variable operating speeds up to 60 km/h, but some access roads have long open stretches traversing easy terrain where it may be feasible and desirable to allow for higher speeds without incurring unjustifiable costs, in which case traditional highway standards may be more appropriate.

2.10 Design vehicle

LVRs should be designed for the prevailing means of transport. For the lowest class access by cars and 4x4 and utility vehicles is sufficient. The design vehicle for the higher classes will normally be a 7-ton truck with a width of 2.6 m. The geometric requirements for accommodating these types of vehicles are well documented and will not be dealt with here.

One potential problem is the possibility of large trucks using the road to transport heavy loads of natural products and resources such as crops, timber, minerals etc. Restrictions on traffic by oversized and overloaded trucks will facilitate more cost effective pavement design, preserve the investment and greatly enhance the road safety for other road users. Ideally, such traffic should be excluded by barriers (with indications of height restrictions at the start of the road) [4]. Use of width and height restriction measures have been used successfully in other parts of the world as a matter of policy [19] and should be considered also in the SSA region.

2.11 Proposed basic LVR geometric design standards

The limited resources available and massive demand for improved rural access should determine the setting of geometric standards for LVRs. Engineers should not be restricted by rigid standards, but should design each road based on its own characteristics in terms of traffic volume, -pattern and -mix, topography and availability of resources. The requirement on LVRs for constant cross-section for the full length of the road segment should be abandoned and narrower carriageways be considered, for instance, on straight sections than on curves or over crests where sight distance is limited [6].

On this basis and the above discussion of factors affecting the geometric design, the following basic geometric standards are proposed, adopting the Design and Traffic Classes from ORN 6:

Table 6: Proposed basic LVR geometric design standards

Road function	Design class	Traffic ADT	Surface type	Roadway width (m)	Passing places
Access	D	100-300	Paved/Unpaved	4.5 – 5.5	As required
	E	20-100	Paved/Unpaved	3.5 - 4.5	As required
	F	<20	Earth/Gravel	3.0 - 3.5	As required

No distinction has been made in this proposal between widths of paved and unpaved roads, nor between types of terrain. Within these general guidelines it is the task of the engineer to fit the road into the environment in the most appropriate manner with the objective to minimise costs and provide adequate levels of service and road safety for all road users.

These cross section widths will generally accommodate typical, but rather infrequent, meeting or overtaking situations between a motorcycle and a car without the motorcycle being forced off the road, and allow adequate space for NMT.

As illustrated below these cross sections can normally be fitted into the available road reserve without acquisition of properties and will therefore cause minimal disturbance to the local population and facilitate a "least cost" design.

Figure 3: Example of widening from 4.5 m to 6.0 m

3. Road Safety

3.1 International research

There is a wealth of international research on road safety on rural roads [6, 7, 13, 14, 15, 16,17, 18], but mostly in the context of relatively high speed rural highway environments. However, many of the recommendations emanating from this research are applicable also in a low speed LVR environment although the law of diminishing returns on accident rates and costs will apply when evaluating the cost effectiveness of these measures.

Some innovative concepts and measures to improve road safety emanating from this research are discussed in the following sections.

3.2 Accident statistics

The high road accident rate in developing countries has, quite rightly, caused road authorities and engineers to focus on accident prevention in road design. However, there is a lack of disaggregated accident statistics, which could provide a rational basis for specific road safety measures and geometric design standards on LVRs.

It would seem to be a logical assumption that accident rates are comparatively much lower in a low speed environment with most road users being familiar with the characteristics of the road, than on high speed rural highways, and this has indeed been supported by research [6], although, as mentioned above, the research has not directly addressed the situation on LVRs as defined in this paper. There is thus as yet no definitive evidence in the accident statistics for excessive widths and rigid standards to improve safety on LVRs.

3.3 Designing for safety

Within the constraints of the available resources, satisfactory road safety can normally be achieved by application of sound engineering principles, such as:

- Striving to make the alignment as self-explanatory as possible and avoiding sudden surprises to the drivers such as hidden curves and junctions.
- Maximising sight distance around curves and on the approach to junctions by clearing the road verges.
- Local widening and lane segregation on potential "black spots" such as sharp crests and blind curves.

Full effect of localised solutions for problem spots will sometimes only be achieved in combination with signage, road marking and speed reducing measures as discussed below.

For LVRs most of these potential problems can be identified with a sufficient degree of accuracy by simply walking and inspecting the alignment. When in doubt the engineer can look up data from standard design manuals and, if required, do detailed surveys of the problematic sections.

Modern road design software packages are built on the design speed concept and will tend to adjust the horizontal and vertical alignment to satisfy the design speed criteria in terms of curve radii, k-values etc. For cost-effective designs of LVRs the engineer should be able to override the output of these packages with the view to minimise horizontal and vertical alignment adjustments with unnecessary cuts and fills and curve straightening, and not blindly follow the survey data that is produced.

3.4 Controlling vehicle operating speed

All research concludes that vehicle operating speed is the number one issue to tackle to improve road safety, both for the drivers and other road users. Operating speed has a clear impact on accident rates and costs as well as severity of damage to people and property. By ensuring that drivers adjust the vehicle operating speed to be commensurate with the geometric design, road environment and traffic volume and composition, adequate road safety can be achieved.

Speed limit enforcement by police is virtually non-existent on LVRs. Therefore, in a similar fashion to making the alignment as far as possible self-explanatory to drivers, engineers should aim to make the roads self-enforcing as regards vehicle operating speeds by judicious use of appropriate and cost-effective speed reducing measures.

It then becomes less important to achieve "ideal" geometric design in terms of road width, curvature, super elevation, side slope gradients etc., and the engineer can concentrate on satisfying the need for reliable and safe access for as many people as possible.

A number of speed reducing measures that have been found to be cost-effective on rural roads [14], include:

- Appropriately located Speed Humps (Watts profile, Flat Top) and Speed Cushions
- Pedestrian crossings at critical locations within villages, at school entrances etc.
- Rumble strips (for warning in combination with other measures)
- Chicanes and restrictions of road width
- Perceptual countermeasures (PCM) such as transverse and hatched road marking
- Signage

All of these, alone or in combination, are applicable both in the inter- and intra-village environment. In the inter-village environment, the measures to be put in place must be assessed on a case by case basis to solve particular road safety problems. Within villages and built-up areas more comprehensive road safety schemes should be designed. Solutions such as the "Village Treatment" described below, or variations thereof, are increasingly being used with positive effects in developed as well as developing countries [17, 18].

It is beyond the scope of this paper to deal with the detailed design of these measures, which can be found in manuals and research literature. The paper will instead focus on some ideas and concepts that are appropriate for LVRs.

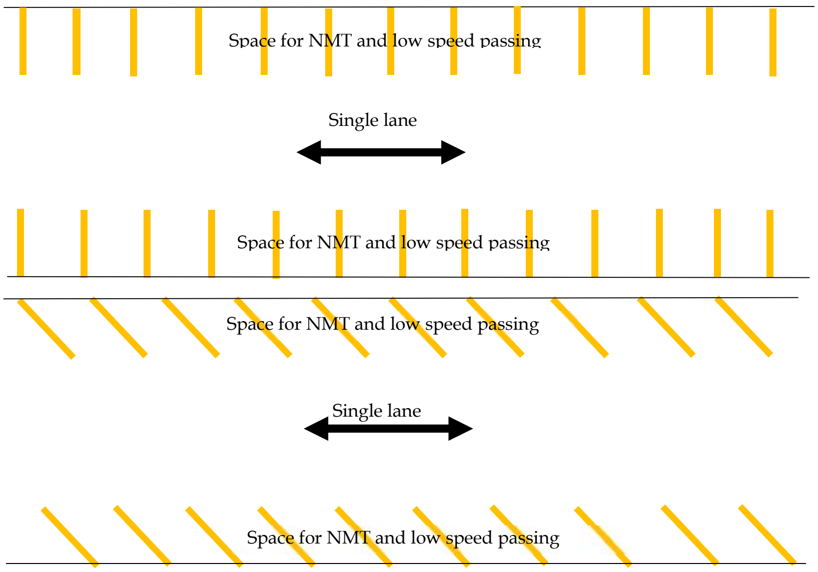
3.5 Perceptual countermeasures

Research has found that drivers' perceptions of their own speed (in the absence of explicit information from a speedometer or vehicle-activated sign) seem to be determined mainly by the optical flow rate in the peripheral vision field. Perceptual countermeasures to speeding can be used to exploit this fact by increasing the visual flow rate without changing the quality of the road [15].

This knowledge has been used successfully on rural highways by using transverse or hatched marking on the side of the lanes on approaches to bridges etc. to give a visual impression that the lane is narrowing. At the same time the road marking is increasing the peripheral visual flow and thereby assisting the drivers to perceive their own speed and slow down as required.

Acknowledging that LVRs effectively operate as single lane roads for most of the time, it is suggested that transverse or hatched road marking as illustrated below could be a cost-effective measure for reducing operating speeds on critical sections and within villages, alone or in combination with other measures. At the same time the marking will demarcate the road sides as being prioritised for NMT, but allowing vehicles to pass each other in a controlled manner.

Figure 4: Transverse or hatched marking on road sides on LVR to demarcate space prioritised for NMT



3.6 The Village Treatment

Traffic calming measures in villages require special attention because the roads serving these villages are often required to serve two conflicting functions in that they must cater for both inter- and intra-village traffic. As a result, traffic entering the village often does so at speeds that are much too high for a village environment with slow moving and turning traffic, parking outside shops and stalls and pedestrians and bicyclists moving along or across the road, often in an unpredictable manner. Such a situation requires the need for a comprehensive "village treatment", which will induce drivers to reduce speed significantly as they pass through a village.

The "total village treatment" has been developed with the objective of instilling in the driver a perception that the village is a low-speed environment in which driving speed should be reduced. In essence, the road through the village is treated as being in three zones, namely:

- The approach zone
- The transition zone

- The core zone.

In each of these zones, an appropriate combination of the various measures described above is judiciously deployed within the village environment.

Figure 5: Village Treatment typical layout

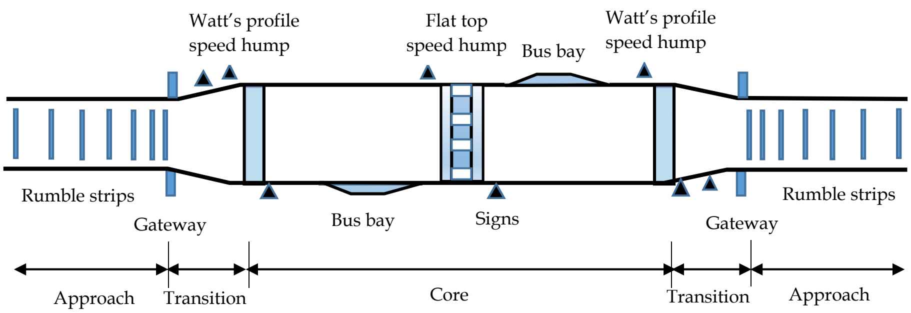


Figure 6:Watts profile speed hump.

Figure 7: Appropriate signage for pedestrian crossing on flat top hump

3.7 Road safety education

Road safety education (RSE) should be a mandatory component of all LVR projects, particularly when roads are upgraded from earth/gravel to paved standard as this tends to increase vehicle operating speed.

RSE is an important tool to raise awareness of problems and behaviours related to traffic and road safety. It involves teaching children, who are often the most vulnerable group of affected road users, and adults to be safer road users. It does so by developing:

- Knowledge and understanding of road traffic.
- Behavioural skills necessary to survive in the presence of road traffic.
- An understanding of their own responsibilities for keeping themselves safe.
- Knowledge of the causes and consequences of road accidents.
- A responsible attitude to their own safety and to the safety of others.

RSE should also address the drivers and operators of public transport vehicles and motorcycles to instil in them a sense of responsibility for assuring the safety of their passengers and other road users.

3.8 Law enforcement

Because of a severe shortage of trained traffic police in rural area, drivers tend to disregard regulations and a general disregard for traffic laws often gradually becomes the norm. This situation highlights the need to promote traffic law enforcement more vigorously, including the use of well mounted campaigns, which ideally should be accompanied by education and publicity.

With the lack of traffic police in rural areas, villagers should be encouraged to form road safety committees to oversee the traffic safety within their "jurisdiction". Without taking the law into their own hands, sanctions - such as by refusing to use particular minibuses or motorcycle taxis - could be applied to public transport operators who are deemed to consistently violate the traffic rules and endanger the safety of passengers and other road users. Voluntary School Patrols could also be guiding traffic at school start and closure times when the roads are teeming with children on their way to and from school.

4. Maintenance

As much as the engineers can design LVRs in a cost-effective manner to provide appropriate levels of service and road safety following these recommended guidelines, concepts and ideas, satisfactory road safety can only be upheld if adequate maintenance activities are carried out in a timely fashion, e.g.:

- Clearing of road verges to maintain sight distances
- Patching of potholes and repair of edge breaks to prevent unpredictable vehicle movements
- Repainting of faint road markings

With the general shortage of resources for provision and maintenance of LVRs, the necessity of designing LVRs at least cost is further emphasised.

5. Conclusion

The massive demand for improved RTI in the SSA region combined with lack of resources demands a much more cost conscious approach to geometric design of LVRs than what is currently recommended in design guidelines and manuals.

Unless a paradigm shift in the approach to geometric design of LVRs is embraced by engineers and practitioners and manifested in government policy, the rural population will be denied their human rights and opportunities for social and economic development.

There is no basis in available accident statistics to justify the current standards, which are based on the traditional design concepts and highway engineers' unfounded perception that increased width and consistent speed environment improves road safety on LVRs.

It has been shown that LVRs with ADT up to about 300 vpd effectively operate as single lane roads for the majority of the time. Engineers should use this fact to their advantage to provide satisfactory road safety levels by judicious use of cost-effective speed reducing measures and perceptive countermeasures to demarcate areas prioritised for NMT. Where required, specially engineered solutions should be applied to localised, potential black spots.

Basic geometric standards are proposed that are more affordable and flexible than current standards, allowing the engineers to design the roads to be **fit for purpose** and

at least cost while providing adequate levels of service and road safety commensurate with the particular traffic level and road environment for each project.

In and around villages and built up areas comprehensive road safety solutions such as the "Village Treatment" should be applied to reduce conflicts and accidents.

Satisfactory road safety can only be upheld if maintenance is carried out correctly and timeously, specifically around critical points to provide adequate sight and stopping distances. This further emphasises the need to re-allocate scarce resources from capital expenditure budgets to recurrent budgets for regular road maintenance.

6. Recommendations for further research

On the basis of the above discussion and the marked change in traffic pattern in the last decade or so, particularly as a result of the rapid increase motorcycle traffic, the geometric design and road safety on LVRs would benefit from further investigations, research and practical trials, including, but not limited to, in the following areas:

- Traffic accidents in rural areas and data gathering for disaggregated accident statistics, with emphasis on LVRs as defined in this paper;
- Effectiveness of various speed reducing and perceptual countermeasures/road marking on LVRs;
- Trials with access restrictions for heavy/oversized vehicles on LVRs, including design/type of barriers;
- Use of different coloured asphalt/surfacing (using pigmented emulsions) as a stand-alone or complementary measure to road marking;
- Road Safety Education schemes – formulation, implementation & effect.

References

[1] Riverson, J., Gaviria, J. & Thriscutt, S. (1991). Rural Roads in Sub-Saharan Africa. *World Bank Technical Paper No 141*.

[2] Mellor, J.W. & Pandy-Lorch, R. (1991). Food aid and development in the MADIA countries. *International Food Policy Research Institute*.

[3] Chinowsky, P., Schweikert, A., Strzepek, N., Manahan, K., Strzepek, K. & Schlosser, A. (2011). Adaptation Advantage to Climate Change Impacts on Road Infrastructure in Africa through 2100. *Working Paper No. 2011/25. UNU-WIDER*.

[4] Lebo, J. & Schelling, D. (2001). Design and Appraisal of Rural Transport Infrastructure: Ensuring Basic Access for Rural Communities. *World Bank Technical Paper No 496*.

[5] Banjo, G., Gordon, H. & Riverson, J. (2012). Rural Transport: Improving its Contribution to Growth and Poverty Reduction in Sub-Saharan Africa. *Working Paper No. 93. The World Bank Sub-Saharan Africa Transport Policy Programme (SSATP).*

[6] Boyce, A. M., McDonald, M, Pearce, M. J. & Robinson, R. (1988). A Review of Geometric Design and Standards for Rural Roads in Developing Countries. *Contractor Report 94. Transport and Road Research Laboratory, UK*.

[7] Oglesby, C. H. & Altenhofen, M. J., (1969). Economics of Design Standards for Low-Volume Rural Roads. *National Cooperative Highway Research Program Report 63, Highway Research Board*.

[8] Overseas Road Note 6. A guide to geometric design (1998). *Transport Research Laboratory, UK.*

[9] Road Geometric Design Manual (2011). *Ministry of Works, Tanzania.*

[10] South Sudan Low Volume Roads Design Manual (2013). *Ministry of Roads and Bridges, South Sudan.*

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[11] Ellis, S.D. & Hine, J.L. (1998). The Provision of Rural Transport Services. *Working Paper No 37. The World Bank Sub-Saharan Africa Transport Policy Programme (SSATP).*

[12] Pinard, M., Paige-Green, P., Rolt, J., & Overby, C. (2015, unpublished). Manual for the Provision of Low Volume Roads. *Second Draft. Ministry of Works, Tanzania*.

[13] Hills, B.L., Baguley, C. L. & Kirk, S. J. (2002). Cost and Safety Efficient Design Study of Rural Roads in Developing Countries. *Project Report PR/INT/242/2002. Transport Research Laboratory Limited, UK*.

[14} Oxley, J., Corben, B., Kopple, S., Fildes, B., Jacques, N., Symmons, M. & Johnston, I. (2004). Cost-Effective Infrastructure Measures on Rural Roads. *Report No. 217. Monash University Accident Research Centre, Australia.*

[15] Edquist, J., Rudin-Brown, C. M & Lenné, M. G. (2009). Road Design Factors and their Interaction with Speed and Speed Limits. *Report No. 298. Monash University Accident Research Centre, Australia.*

[16] Martindale, A & Urlich, C. (2010). Effectiveness of transverse road markings on reducing vehicle speeds. *Research report 423. NZ Transport Agency*.

[17] Rural Minor Roads Traffic Calming. Information Sheet FF38 (2004). *Retrieved from http://www.sustrans.org.uk/sites/default/files/documents/rural20road20traffic20calming.pdf*

Ilho#Frgh#Fkdqjhg

[18] Speed Reduction Measures in Villages, The Village Treatment (2000). *Ministry of Works and Energy, Fiji Suva.*

[19] Republic of Cambodia Rural Infrastructure Programme Phase IV and V. *Terms of Reference, Ref. No.: BMZ 2013.6530.3, KfW, Germany*