Urban road design in Africa: the role of traffic calming facilities

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ABSTRACT: In Dar es Salaam and Morogoro, Tanzania, a range of traffic calming interventions were implemented in 1996-99. Their immediate effects have been reported earlier. This paper summarises an evaluation of their long-term impact, with the aim to increase understanding of the performance of various traffic calming facilities in African road and traffic conditions, in particular: their lasting impact on traffic safety and efficiency, and their maintenance requirements.

The most important finding is the great effectiveness of the raised zebra crossing. This facility has a very positive permanent effect on the traffic flow, has low maintenance requirements (if well designed and constructed) and, combined with other measures (a/o the systematic use of minibus bays/platforms) can play an important role in increasing the efficiency of informal public transport. The long-term impact of a range of other interventions is also documented in the paper.

RÉSUMÉ : A Dar es Salaam et Morogoro (Tanzanie), une série d'interventions visant à calmer la circulation a été mise en oeuvre dans les années 1996-99. Leurs effets immédiats ont été annoncés précédemment. La communication récapitule une évaluation de leur impact à long terme, avec le but d'augmenter la compréhension de la performance de divers équipements visant à calmer la circulation sur la route africaine et les conditions de trafic, en particulier : leur impact durable sur la sécurité et l'efficacité de la circulation et leurs exigences en matière de maintenance.

La découverte la plus importante est la grande efficacité des passages piétons surélevés. Cet équipement a un effet permanent très positif sur le flux de trafic, a de faibles exigences en matière de maintenance (s'il est bien conçu et construit) et, combiné avec d'autres mesures (et/ou l'utilisation systématique de quais pour les minibus), il peut jouer un rôle important dans l'augmentation de l'efficacité des transports publics informels. L'impact à long terme d'une série d'autres interventions est aussi détaillé dans la communication.

1. INTRODUCTION

This paper summarises a long-term impact evaluation of the performance of traffic calming interventions (de Langen ea. 2003). These were implemented in Dar es Salaam and Morogoro, Tanzania in '96-2000, as tests within the Worldbank SSATP. The evaluation combines direct site and traffic observations and discussions with municipal experts. Its aim is to draw final conclusions about the "value for money" and effectiveness of the interventions. An additional source of information is a MSc thesis evaluating recently constructed traffic calming facilities in Nairobi (Mburu, 2002).

Most interventions discussed below are 4-7 years old. Their maintenance requirements can now be judged properly. The same is true for their lasting impact on the traffic. Therefore, the present evaluation, although more general and involving less data analysis, can draw conclusions with more certainty than the earlier evaluations that were carried out immediately after implementation (a/o Kisisa, 1998a,b). Of some interventions reported on here the effects have not been presented earlier. This concerns roads rehabilitated in Morogoro in 2000/01 under the Tanzanian Urban Sector Rehabilitation Project. Design recommendations for these roads were given in 1999 by the team that implemented the other WB SSATP test interventions discussed here.

The evaluation findings underline the importance of research of the impacts of different types of road and traffic-facility design on urban traffic in Africa. Which designs are chosen really matters. The choices have great impact on the performance of the traffic system. Proper design choices are a powerful instrument to improve urban traffic performance and mobility in Africa to the benefit of its large majority of inhabitants that are captive pedestrians, public transport or private two-wheeler users.

In the UNCHS Sustainable Cities Programme, an expert network on low-cost urban mobility has been initiated recently, with the aim to stimulate such research and the development of improved urban mobility policies and road design standards. From early 2004 onwards, research on the issues dealt with here will be communicated through this network.

2. SUMMARY OF FINDINGS

2.1 Raised zebra crossings

So-called Raised Zebra Crossings (RZC) give very good value for money as a traffic calming measure. They create a strong improvement in traffic safety for pedestrians (safer crossing in particular), two-wheelers (safer driving on the carriageway), and motor vehicles (less collisions), and also influence the fluidity of the traffic flow positively by reducing large speed differences between vehicles. In that manner they increase road capacity. In addition, RZC's turn out to influence the stopping-for-passengers behaviour of informal public transport vehicles in a way that can be utilised to significantly reduce the delays that this behaviour causes (see below under bus bays).

The strong reduction in traffic accidents created by RZC's observed immediately after their construction is a permanent feature (Kisisa 1998, de Langen & Tembele 2001, de Langen 2003). Accident reduction does not gradually fade away the more everyone gets fully used to the new situation. This is a very important conclusion

At many locations, pedestrian crossing on top is not important, the RZC function is purely a vehicle speed control one. RZC vehicle speed reduction always works. It is not possible for drivers to ignore it, unlike e.g. the carriageway deflection past a traffic island (which some drivers "compensate" by dangerous driving), or traffic lights, or speed limits, or painted-only pedestrian crossings.

Where pedestrian crossing is a vital aspect, the RZC should preferably be 5-6 m wide, well connected to walkways, bus bays and footpaths leading to the crossing point, and clearly visible as a crossing point.

Although effectively creating safe crossing points, the general impact of the systematic application of RZC's along the entire road length is that the traffic becomes significantly safer in general, and that many pedestrians cross -safely- elsewhere, often near a RZC. This pedestrian crossing pattern observed in 2003 is identical to what was observed immediately after project implementation in 1997. Apparently the pattern is stable, no gradual concentration of pedestrian flows to RZC locations takes place. It should be noted that such a more dispersed pedestrian crossing pattern *reduces* delays that motor vehicles experience from crossing pedestrians.

It is very important that where a RZC is constructed storm water drainage is good. No water should be able to accumulate on the pavement in front of the RZC or on the road shoulder next to it. Where this happens the road base will become soft and pavement damage will build up. Potentially, the RZC impedes the storm water run-off, and -due to vehicles humping up or down- vertical pressures on the pavement in front of the RZC are higher than elsewhere, so road base strength (compaction) at the RZC spot is of critical importance. At some test intervention spots storm water drainage was insufficient, and this triggered pavement damage.

Assuming proper storm water drainage and proper road base compaction/strength and concrete quality, the technical life of a RZC with pre-cast concrete sloping blocks and brick pavement on the raised part can be estimated at 25-30 years. On average, periodic maintenance (relaying brickwork) will be required every 8 years. The lifetime of RZC's is significantly higher than the 10 years assumed when the interventions were first designed. This means that the B/C ratio of RZC investments is higher than the 1.75 calculated earlier (de Langen 2001).

In DSM, the effectiveness of the RZC and its "value-for-money" has been generally recognised by the market. Many applications can be seen on new and rehabilitated roads now. This is an extra reason for the municipal government to lay down precise detailed design guidelines for RZC.

The vehicle speed reduction achieved by a RZC depends on its slope and slightly, but much less on its height (10-12 cm is enough if a straight slope is used). Therefore, by a suitable choice of the slope of the concrete sloping block the desired speed reduction can be obtained permanently. The shape of the transition between the flat top and the slope is of considerable influence on the speed reduction impact. A design with concrete sloping blocks, a straight slope without asphalt overlay, a brick pavement on the raised section and a non-rounded transition between the slope and the brick section reduces speed considerably more than a RZC design with sinus shaped slopes (often used in Europe).

Slope/height specifications for different road types and speed reduction targets are to be worked out in detail. Some additional research is required for this. The current best estimate for African traffic and vehicle fleet conditions is that, with a straight slope design, a slope of 1:8 reduces the speed to around 10-15 km/hr, a slope of 1:10 to 20-25 km/hr, and a slope of 1:12 to 30-40 km/hr. (de Langen and Tembele 2001, chapter 15, design 18).

The wide-spread application of RZC's should be enhanced, and they should be included as a standard element in urban road design standards prescribed by the municipal government.

2.2. Asphalt concrete speed hump compared to RZC

The main purpose of testing the conventional speed humps side by side with RZC's in the WB SSATP pilot projects was to compare their performance. In 2003, the humps constructed in Temeke continue to slow down the traffic as intended. However, their pavement has deteriorated significantly in the 5 year period since they were constructed (deformation of the hump itself) and the surrounding carriageway pavement shows more potholes than in case of RZC's. Over time. the RZC's perform significantly better than the humps.

The conclusion now is that RZC's are superior to asphalt-concrete speed humps as a traffic calming facility:

- lower RZC life-cycle cost. Although its initial construction is cheaper (60-70% of RZC costs), the asphalt hump has much higher maintenance/ rehabilitation cost, and creates a much higher risk of pavement damage near the hump in case of insufficient drainage or road base compaction (due to the higher vertical forces it generates).
- RZC's are considerably more comfortable for vehicles (compared to asphalt humps that create the same speed reduction effect).
- RZC's are dimensionally stable, their impact is constant over time. Asphalt concrete humps deform gradually and thus become less effective.

Recent evaluation of the impact of speed humps in Nairobi is worth including here (Mburu, 2002). On Nile road (Eastlands), three humps were constructed in 1996 as traffic calming measure, as part of the WB SSATP tests. Their positive effect on traffic safety was such that residents along nearby roads started urging NCC to construct more humps, which it did in 1998-99. Analysis of traffic accident data for the roads concerned shows that, as in the case of RZC's, application of humps on a road section significantly reduces the number of accidents. It also shows that where the distance between two humps is large (in this case around 600 m) the accident risk remains high in the middle of that section. This underlines the importance of a careful choice of the locations of humps/RZC's, in relation to important crossing pedestrian routes, bus stops, road corners, intersections and nearby humps.

2.2.1. The effects of humps on route choice. Another interesting finding reported in the same study was the effect of the humps on route choice of cars.

Contrary to the expectation (that drivers would prefer arterial roads without humps), the influence of humps on route choice was found to be unimportant. During the peak, when the roads with humps can be used as an alternative to avoid a small part of the traffic jam, the discomfort caused by the humps does not discourage drivers from doing so, even though the travel time is approximately the same on all routes. Comparing four routes between the same origin and destination, one (A) entirely on arterial roads and the three others via different collector roads, the following was found:

Peak hour average travel time and average speed on alternative routes in Nairobi, Eastlands (2001) (Mburu, 2002).

route	length (km)	# humps	travel time (min)	average speed
A	8.2	2	19.8	24.8
B	7.9	15	20.4	23.1
C	7.9	17	20.4	23.2
D	6.2	30	19.5	18.5

Routes B, C and D all branch off route A at the same intersection (after 400 m). During the peak around 60% of the drivers at this point select route B, C or D, while 40% take A. In the off-peak around 80% take route A here, which at that time of the day is 2-4 minutes faster than B, C or D. Taking out drivers with no real choice, because their destination is not the common endpoint of A-D, an estimated 80% in the peak prefers the more quiet collector roads with humps, while in the off-peak 90% prefers the then slightly faster arterial route. The observed lower average speed on route D is caused by the queue at the point where D merges back into A, not by the humps along D.

The expected travel time thus appears to be the decisive factor, while the "comfort" argument does not play a role. This is a relevant conclusion, since in public lobbying against the construction of traffic calming measures such as RZC's or humps on arterial roads the comfort argument invariably comes up strongly.

2.3. Bus bay, passenger platform, RZC combination

The 2003 evaluation reconfirms the effects of well designed bus bay/RZC combinations that were found immediately after construction (Rwebangira 1998). The bays have established themselves as the only relevant points to pick or drop passengers along the road section concerned. Some bays turn out to be slightly too small in the peak hour, which resulted in some pavement/roadshoulder damage at their exit.

The strength of the bus bay design that was adopted, with a brick pavement in the bay, heavy kerbs and slab pavement on the passenger platform, is found to be very satisfactory. No maintenance (apart from regular cleaning) has been carried out yet (after 4-6 years), and -for the bay pavement- will probably not be needed for the next 3 years (first relaying of the bricks after around 8 years). A significant advantage of the brick pavement in the bus bays is that it is not affected by oil leakage from the buses, unlike asphalt concrete, which quickly gets soft and then damaged as a result of leaking oil.

The conclusion is that bays for minibuses give high value for money, once the following requirements are met: proper size (large) and frequency along the bus route, combination with paved passenger platform, location at points that logically connect with walking routes, combination with RZC for low motor vehicle speed near the stop and safe pedestrian crossing, combination with a road design that prohibits stopping on road shoulders outside bus bays.

Bays combined with these other measures reduce traffic delays (both for mini buses and general traffic) and reduce traffic accident risks, previously caused by random stops of buses on or half-on the carriageway.

Well constructed bay facilities also increase the economic attractiveness of their location (a/o visible from increased kiosk and street trading density).

In co-operation with the (mini-)bus operators, one should try to exploit the potential of this road design approach to encourage the sector to improve its operational efficiency.

2.4. Carriageway / road-shoulder separation to assure space for and safety of pedestrians

Systematic use of road design features and road furniture to separate the motor vehicle carriageway from the pedestrian road-reserve area (whether constructed as walkway or not) is effective and significantly enhances safe and efficient pedestrian movement. Where “road shoulders” are allocated to pedestrian traffic and protected against use by vehicles this safeguards the safety and efficiency of walking. The main separation options are road furniture such as low triangular concrete blocks and bollards, or open drains.

T-block, bollard. Looking at cariageway/shoulder separations by means of concrete blocks or bollards 4-6 years after their construction instantly makes clear that this type of traffic calming measure requires careful regular maintenance. The amount of damage, uprooting and knocked-off parts of the concrete, is large. Depending on the location, over 50 % of all elements is damaged. Even though in most cases it does not make them ineffective as a separation, the damage has a negative effect by creating a run-down image and stimulating careless behaviour. The main cause of damage is a vehicle that hits a blocks or bollard. Hitting with a tyre usually only results in a block being pushed out of position (particularly by heavy vehicles). Notching off concrete suggests contact between the block or bollard and the body of the vehicle. The number of drivers that do not manage to keep their vehicle on the carriageway appears to be alarmingly high. It is interesting to investigate the actual frequency. Seeing that so many “hits” occur, how to react? One does of course feel sorry for car drivers that damage their cars. But one can also not avoid to think what would have happened if the block or bollard had not been there. Would the driver have ended up against one of the trees, or a pedestrian, or a street vendor, or a parked vehicle? Such an alternative collision would have been much more harmful. If only 10% of the damage to the road furniture signals such prevented mishaps, the road furniture is even better value for money than one thought. If indeed the damage to the blocks mainly relates to incompetent driving or non road-worthy vehicles (drunk driving, driving at night without proper lights, failing brakes etc.), the conclusion has to be that the blocks and bollards serve a very useful “sleeping policeman” purpose, and contribute positively to the enforcement of proper driving behaviour.

On many places along urban roads, containing the motor vehicles on the carriageway by means of road furniture contributes significantly to the efficiency of traffic flows, both of vehicles and of pedestrians. However, the highly recommendable systematic use of this traffic calming instrument must be accompanied by equally systematic maintenance. Such maintenance mainly involves labour. It does not cost much, but requires good organisation.

Open road-drains were found to function very well as separators. Moreover, they seem to convince drivers that it is better to reduce speed, probably in view of the unpleasant and expensive consequences of driving into a drain. Observation of the traffic behaviour on a completely reconstructed road in Morogoro, designed with a wide carriageway (4.5m each way, of which the outer 1.5 m as bicycle lane -

painted separation only), and walkways on both sides behind open drains, indicates that this design increases the efficiency of the traffic flow (much less pedestrians on the carriageway, hardly any traffic conflicts between cyclist -many in Morogoro- and motor vehicles, and less disturbance by wrongly parked vehicles). It should be noted that the traffic safety on this road was assured by the construction of RZC's at regular intervals (3-400 m). Without these, some of the vehicles would drive at a much too high speed and create a considerable accident risk.

2.5. Pedestrian crossing islands

Given the prevailing driver behaviour, a small pedestrian refuge island is ineffective as a means to simultaneously facilitate pedestrian crossing and achieve a significant "no-discomfort" traffic calming (in particular vehicle speed reduction) effect. The test was carried out in Dar es Salaam, but there is no reason to assume a different outcome in other African cities. Considering all effects, the conclusion has to be that short mid-block pedestrian crossing island must be advised against in African cities.

These small traffic islands turn out to have a number of undesirable effects:

- ⇒ The reduction in vehicle speed that is achieved reduces over time, at least part of the drivers learn and like to drive fast past the island.
- ⇒ The shortness of the islands (12 m), good visibility of the on-coming traffic and a lack of respect for traffic rules tempt some drivers to use the opposing lane to overtake, dangerously.
- ⇒ The problem of incompetent drivers (see above) is unnecessarily aggravated by this type of island.

The conclusion about small mid-block pedestrian crossing islands should not be generalised to all forms of traffic island. The following other applications remain worth considering.

- ⇒ Traffic island in the single-leg of a T-junction.
- ⇒ Traffic islands at an intersection.
- ⇒ A large mid-block crossing island where a high-volume NMT-route crosses a high volume road.
- ⇒ A long median in a 2x1 urban road . The traffic calming effect is that this eliminates overtaking (tested in Eldoret, Kenya).

2.6. Junction reshaping

Conversion of Y-shaped junctions to rectangular, and reduction of road corner radius are an effective "no-discomfort" instrument to reduce the speed of motor vehicles that turn into the street concerned. Such a change in road shape works immediately (as shown during the monitoring in 1998/99), and its effect remains the same over time, as is clear now. Drivers do not gradually increase speed or develop other dangerous type of behaviour once they get fully used to the new shape (unlike in the case of short traffic islands).

2.7 Carriageway width

The use of 3.0 m wide carriageway lanes was tested in Morogoro, on the main (2x1 lane) arterial road connecting the city centre to the Tanzam highway, which was redesigned and rehabilitated in 2000/01. Access on the main carriageway is allowed for motor vehicles only. The design has open drains, with a 0.5 m shoulder between the carriageway and the edge of the drain, bicycles and pedestrians are provided with separate tracks of their own on one side of the road, behind the drain. The road is in use for two years now, and functions very well. The design is significantly narrower than is now common in Tanzania for such a road (usual is 3.5 m lanes and a 1.0 m shoulder). It was looked at from several sides with suspicion. In practice, the narrow carriageway encourages safer and slower driving, convincingly shows the driver that he is in an urban area now and must adapt speed. The nearness of the open drain significantly contributes to the effect.

The narrow width equally appears to discourage cyclists from using the MT carriageway, and enhances that they use the track provided for them, even though this is only provided on one side of the road (bi-directional). A more detailed monitoring of traffic behaviour on this road is desirable before generalising the findings to other situations. However, the indication given by the current brief evaluation of this road design is quite relevant, not in the last place because of its implication for the construction costs. The cost saving achieved by using a narrower MT carriageway was large enough to pay for the separate bicycle and walkway facilities.

3. IMPLICATIONS FOR URBAN ROAD DESIGN IN AFRICA

Evaluation of the long-term impacts of a range of test with traffic calming facilities and road designs yields interesting findings. The most important one is that a few straight-forward traffic calming instruments exist that perform excellently in African traffic conditions, continue to work well in the long run, and have a high benefit cost ratio.

From a comparison of different traffic calming options it becomes clear the most elementary and robust ones are also the most successful ones, and that large scale improvement is a matter of large scale application of the elementary traffic calming devices, not of creating complex solutions.

1. Generally speaking, the key is: make it impossible to drive through the city at a speed above around 50 km/hr, by constructing short raised road sections that penalise drivers decisively for trying to break this rule. Raised pedestrian crossing sections have been tested and work well, raised intersection platforms with similar slope designs will probably also work well. This measure reduces traffic accident hazards dramatically, as it reduces the severity of the remaining accidents. As a side-effect, two-wheeler traffic becomes safe enough again to be utilised for those travel market segments for which it is the economically most attractive option.

2. Next: accept that pedestrian traffic has an overwhelming presence and great economic and social importance in all cities in Africa, and provide for it. Separation of pedestrians from vehicles on the carriageway is very cost effective. Safety and efficiency of both vehicle traffic and pedestrian traffic increase considerably. Ignoring or wishing away the pedestrians so far never produced good results.

3. Next: create an efficient interface between public transport and pedestrian access and egress trips, accepting the market position and proven effectiveness of informal public transport, but at the same time reducing the loss of traffic flow efficiency caused by some of its operating practices.

Implementing the agenda outline above is a task demanding all resources that are available to take care of the existing urban traffic systems -in combination with road pavement maintenance, building new access roads in non-served urban expansion areas and creating sufficient capacity on the main arterial roads. Adding more is counter productive.

The main unanswered question with respect to the traffic calming policies outlined above is: how to shape them for the main arterial roads? A discussion of that question -unfortunately- is outside the scope of this paper, and demands tests beyond the tests of which this paper summarises the findings.

3.1. Can an intrinsically safe urban traffic infrastructure be built?

Carefully interpreting the findings presented above leads to the conclusion that it might be possible to gradually redesign and reconstruct most roads in African cities in such a manner that a so-called “intrinsically” safe and reasonably efficient traffic system is created. This challenge can be compared to that of designing an intrinsically safe nuclear reactor.

Nuclear reactors are known to be quite safe, but if something goes wrong it can go very wrong, and if risk control includes human operators that must do the right thing at the right moment it is impossible to trust that everything will always go well. Hence the need for a design that of its own, without control system involvement, prevents situations in which a beginning accident can get out of hand completely, by proper choice of the design parameters of the facility.

Traffic systems are quite different from nuclear reactors of course: very small risk, but in case of an accident a catastrophic one, versus considerable risk of nasty but localised and -at system scale- small accidents.

Yet, as we all know, urban traffic systems can get out of hand considerably, and successful examples of regaining control by means of traffic police, driving licences, traffic education, an appeal at good driver behaviour, electronic traffic control and guidance, etc. have so far not emerged in Africa.

Therefore: would it be possible to make intrinsically safe and efficient road designs, i.e. roads designed in such a manner that the traffic flow remains reasonably safe and efficient, even if the traffic police cannot enforce well behaved road use, even if relevant numbers of drivers are incompetent, and relevant numbers of vehicles are in terrible technical condition, even if traffic lights are out of order regularly? It would be simplistic to assume that the full-scale application of an elementary set of traffic calming facilities would create a miracle. Yet, it is worth reflecting on how far one could get towards the provision of road infrastructure that leaves significantly less room for abuse and large scale system malperformance caused by wrongful use.

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