Civil and Environmental Research www.iiste.org
ISSN 2224-5790 (Paper) ISSN 2225-0514 (Online)
Vol.8, No.1, 2016

Use of Portable Speed Humps Near Schools for an Obstruction-Free Traffic Flow during Holidays

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Abstract
Speed breakers or speed humps are known to provide road users with increased safety if strategically placed, especially in pedestrian intensive areas. Such traffic calming measures are common in land-uses where streets provide direct access to homes, hospitals, transit stops, and schools. In cities and towns of developing countries like India, it is common to construct at least two hump-like speed breakers, near the entry and exit gates of every school that provides primary, secondary and higher secondary education. The purpose of such speed breakers is to provide safety for students, staff and parents who access the school. However, as speed breakers are built as permanent structures, vehicles passing over them during non-operational hours as well as long holidays need to slow down for no reason. Portable speed breakers seem suitable for school areas to allow an obstruction-free traffic flow if and when possible. In this paper, results of a simulation evaluation of such portable speed breakers are presented, with quantification of benefits in terms of travel speed and travel time savings.
Keywords: Speed breaker; speed hump; portable speed breaker; traffic calming; simulation modeling; traffic safety.

1. Introduction

Speed humps, also known as speed breakers, are well known means of traffic calming devices (Kadiyali 2014). A speed hump is a raised section on road pavement marked clearly for drivers to respond with a speed reduction. Recommended dimensions from Indian Roads Congress are as follows. The travel length shall be from 4 to 5m and height shall be around 10 cm with a smooth curved gradient (IRC 1996). However, it is common to build speed breakers with varying sizes and shapes on the streets of Indian towns and cities. There are also speed 'bumps' with travel lengths as short as 0.3m (ISU 2009). A series of such bumps are constructed at places where there are more chances of speed-related accidents.

When strategically located, speed breakers can prove to be instrumental in improving traffic safety in a network of local streets (Kadiyali 2014, IRC 1996). Drivers approaching a speed hump tend to reduce their speed to avoid a bumpy ride and thereby decrease the chances of speed-related collisions that might otherwise occur due to higher speeds. According to Indian Roads Congress, speed breakers are warranted at T-junctions and minor streets connecting to major roads with a history of speed-related accidents (IRC 1996).

Speed breakers are also recommended to be installed on streets that provide access to residential areas, hospitals, and educational institutions such as schools, colleges and universities (IRC 1996). These are the land uses where pedestrian interaction with regular traffic is predominant.

In developing countries like India, most of the schools do not have a dedicated driveway or service road. The entry or exit gates face the streets that carry regular through traffic. It is therefore a common practice to install speed breakers in the form of humps or bumps on the streets from where schools are accessed. The term 'school' is used here to refer to any of the educational institution that offer primary, secondary or higher secondary education. It also includes pre-primary, upper-primary, intermediate secondary and other such schools that offer pre-undergraduate education as categorized in Indian statistics records (GI 2012). These are the institutes that provide students with long holidays or vacation period of one to two months every year. There will be hardly any pedestrian interaction during these periods. Yet, vehicles using those streets are subjected to a speed reduction, which is rather unjustified. An opportunity of obstruction-free travel is overlooked here due to the provision of speed humps as permanent structures. If speed breakers can be removed during non-operational days of the school, say, by using any suitable type of portable speed breakers available in the market, an obstruction-free travel can be facilitated to every vehicle using those streets.

Furthermore, the benefits of not having speed humps extend beyond allowing a free flow travel. Speed breakers cause discomfort to drivers and passengers. Unexpected speed breakers often cause incidents for drivers who are unable to control speed at a short notice. Damage to vehicle suspension especially for two-wheelers is also a known complaint about speed humps. While these inconveniences are often reported by the media, there are some demerits of speed humps well documented in literature. Speed humps are reported to have caused injuries to drivers as well as passengers of vehicles (Hessling and Zhu 2008). Munjin *et al* found that people seated in last row of buses could suffer severe spine injuries when the vehicle passes over speed humps (Munjin *et al* 2011). An increase in fuel consumption and an increase in polluting emissions are reported as a result of acceleration of vehicles just after crossing speed humps (Ahn and Rakha 2009). Pavement distress effects due to deceleration and acceleration near speed humps are also reported (Bekheet 2014). Emergency vehicles such as fire trucks and ambulances often find it difficult to pass over speed humps (CEDD 2009). Roadway noise due to deceleration and acceleration is inevitable when vehicles pass over speed humps (SCRC 2008).

Removing a permanent speed breaker and installing a new portable hump involves financial resources. Therefore, it is necessary to study the traffic conditions that might show significant benefits when switching to portable humps. This study aims for quantifying key benefits such as savings in travel time. The study also aims at measuring speed reductions caused by speed humps, which are indirectly the speeds that can be achieved in the absence of speed humps. Every unit saved in travel time, fuel consumption and fuel emission can attribute to a significantly large savings to the community at large, considering the fact that there are around 1.4 million schools in India alone (GI 2012).

2. Methodology

Microscopic simulation had been a preferred way to study about speed humps, due to the convenience and possibilities of generating detailed performance outputs for analysis (Lee *et al* 2013, Garcia *et al* 2011, Kanjanavapastit and Thitinaruemit 2013). TrafPlus, a microscopic simulation software is used in this study (TrafPlus 2015).

2.1 TrafPlus Simulation

Popular traffic simulation programs such as PARAMICS, VISSIM and AIMSUN are more suitable for modeling homogeneous traffic conditions in which cars are the predominant mode in the traffic mix (Hidas 2005). However, in developing countries like India, modal split has around 30-40% of fast two wheelers and auto-rickshaws (UNEP 2009). In Hanoi, Vietnam it is as high as 48% (UNEP 2009). Furthermore, traffic does not flow in queues when the traffic mix is highly heterogeneous. Small vehicles tend to find space between large vehicles and hence regular queuing does not occur. This means that a major portion of the traffic cannot be modeled to follow a well-behaved queuing pattern. The way mixed traffic is modeled can affect the number of vehicles that can pass over a road section. As such, programs developed with core models to represent homogeneous traffic might not be directly suitable for this study without tedious calibration and validation processes. Hence, TrafPlus a model developed for mixed traffic conditions is chosen for this study.

TrafPlus uses typical car following, lane changing and gap acceptance laws for individual vehicle movements on the lanes of a road, where applicable. In addition, small vehicles are modeled to use the space between lanes to create a mixed traffic condition as shown in Figure 1. Note that for a street with one lane, small vehicles occupy edges of the street rather than following a queue behind cars or big vehicles. This is a characteristic of mixed traffic situation found in urban areas of developing countries.

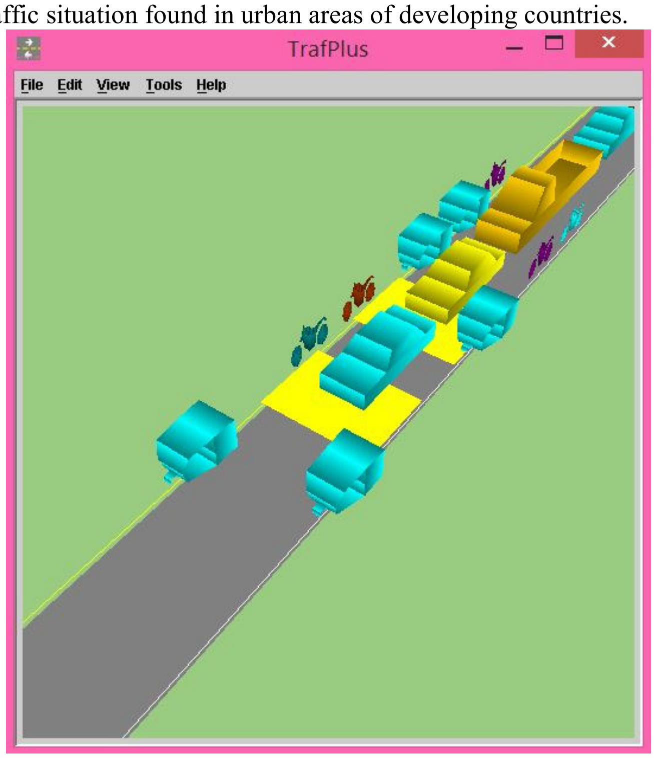

Figure 1. Snapshot of TrafPlus Traffic Simulation

In TrafPlus modeling, speed hump is a feature under traffic flow constraints category. Speed breakers can be specified anywhere along a road (or a link in simulation modeling terms). TrafPlus treats it as a type of hazard, where vehicles will approach it as if it is approaching a stop line at signal on red. Vehicles will then pass over the speed hump at near zero speed. Once the breaker is crossed, vehicles will accelerate to reach their target speeds. The speed at which a vehicle crosses a speed hump is critical as it influences travel time measurements. TrafPlus uses a non-zero random value as the cross-over speed limited to 5 km/hr, following a uniform distribution. This adheres sufficiently to the speed profiles on humps documented elsewhere (Tiwari 2009).

Speed humps are represented in simulation as yellow regions on the road as seen in Figure 1. Theoretically, the midpoint of the speed hump is the target for vehicles to reach the lowest speed while crossing over the hump. The low speed is maintained until the both axles of the vehicle passes over the speed hump.

2.2 Model Configuration

The simplest case of location of speed humps near a school gate is shown in Figure 2. The street can be one-way or two-way, with or without a median. Street width is set to represent one lane only (4m). This is to find the minimum benefits that can be achieved by means of using portable speed breakers. Any increase in the number of lanes is assumed to produce proportionally higher benefits. The length of road section is set to 1 km. This length is found sufficient enough to accommodate queues developed at speed humps during high flow conditions simulated.

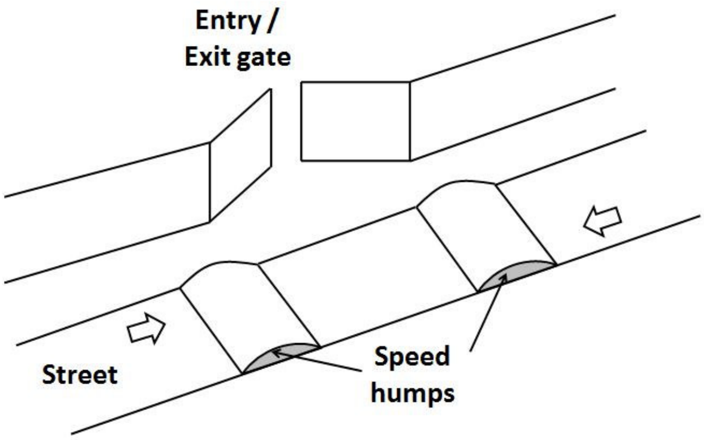

Figure 2. Typical Speed Hump Locations near Schools

The spacing between humps usually is equal to or greater than the size of entry or exit gate. Five spacing values are simulated: 5, 10, 15, 20 and 50m. This is to include a variety of spacing of humps observed at school sites visited for the purpose of this study. A spacing that is more than 50m seems to represent two isolated speed humps on a street, rather than one set of humps causing a combined effect. The interest here is to find the effects of speed humps in their typical configuration near school areas. Therefore, every case has a set of two speed humps located at different reasonable spacing.

Five different traffic flow levels are considered: 500, 1000, 1500, 2000, 2500 and 3000 vehicles per hour per lane. A flow value of as high as 3000 vehicles per hour in a highly mixed traffic condition is not the same 3000 cars per hour per lane in a homogeneous traffic conditions made of mostly cars. Therefore, such high flow levels are not beyond saturation capacity of a single lane street subjected to mixed traffic conditions considered in this study. Speed humps are placed at the middle of the 1 km long street.

Further analysis is based on the output data generated by simulation performed for five different spacing values under six different flow conditions. The case with no speed humps is simulated as the base case for all the six flow conditions.

3. Analysis

TrafPlus generates output data for a variety of measures of effectiveness at node (junction), link (road segment) and network levels. Every run produces one set of output data. Vehicle count per hour (or the flow) is measured for cross checking purposes (described later). Mean speed and mean travel time along the street section modeled are the key output data used for analysis. Mean speed is the average of speed values measured for every vehicle, every timestep of its existence in the simulation environment (from release to reaching the destination). Unit is km per hour. Similarly, mean travel time is the average of travel times measured for all the vehicles that entered into the system. Unit used is minutes per vehicle. Here, the 'system' is analogous to the single lane road section modeled. If a large network is studied, separate link level and trip level statistics might be necessary.

For each case, simulation was run for one hour of field time. Since the road section modeled is just 1km with no obstructions, equilibrium issues do not arise; vehicles released into the road do reach the destination, which is the other end of the road.

First, the input and output flows are checked. Then speed measurements are compared across different scenarios. This is followed by a similar comparison of travel time measurements. Any reduction in speed due to speed hump will represent the opportunity of free flow travel lost during vacation or holiday time because of the presence of speed humps.

3.1 Traffic Flow Analysis

It is necessary to compare the number of vehicles that passed over the speed humps with the number of vehicles expected to pass over (specified as the input flow). This is to make sure that any delay measured is due to the speed humps and not due to interactions between vehicles at high flow levels. Figure 3 shows measured flow and input flow for all the cases modeled.

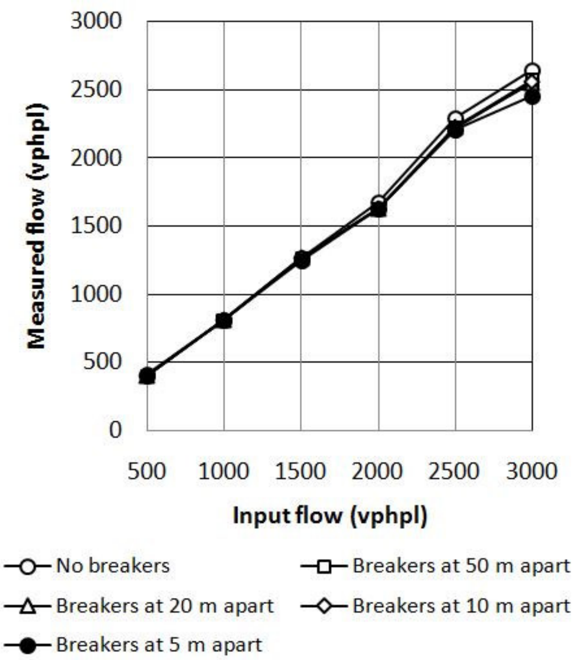

Figure 3. Measured and Input Flow Comparison

For flow values that are equal or lower than 2000 vphpl, measured output flow remains as same as the input flow. It happens irrespective of the spacing of humps. This shows that no queues are formed at humps. Hence, no vehicles are held from reaching the other end of the road.

At higher flows of 2500 and 3000 vphpl, measured output flow differs from input flow. Shorter the spacing between humps, higher the deviation of measured flow from desired flow. For humps spaced at 5m, the measured output flow seems to largely differ from the specified input flow. This indicates that vehicles are held in queues formed at speed humps at the expiry of one hour (the duration of simulation) and hence, did not arrive at the other end of the road yet.

3.2 Traffic Speed Analysis

The purpose of speed humps is to achieve a reduction in vehicle speed. Figure 4 confirms this expectation in every case with speed humps installed. Even the scenario of the lowest flow of 500 vphpl shows a notable reduction in speed when compared to the base case of hump-free condition. Earlier, flow comparisons showed that there was no change in measured output flow with respect to specified input flow, at low flow conditions. Therefore, speed reduction at low flow conditions is entirely due to presence of humps and not due to holding of vehicles in any queue formation at humps.

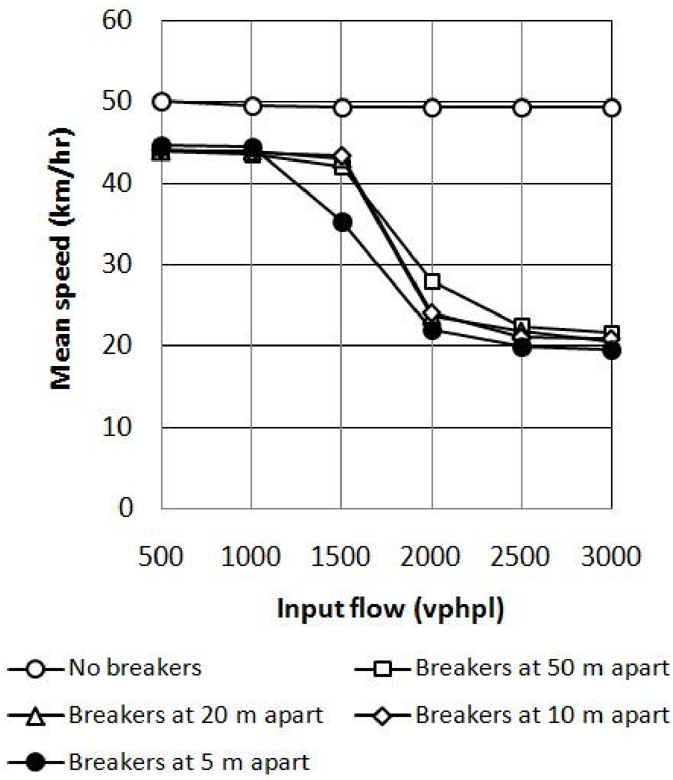

Figure 4. Effect of Speed Humps on Speed

In simulation setup, the speed limit for the road section was set to 50 km/hr. Hence, the base case of hump-free condition shows a mean speed reaching 50 km/hr. A reduction in speed is seen for the base case, as flow increases. This reduction is relatively insignificant compared to the effects of humps.

At high flow levels of 2000 vphpl and above, speed reductions are more pronounced. Earlier comparison of input and output flows showed that queue building occurs at speed humps so as to reduce the number of vehicles reaching the other end of the road. Therefore, at high flow levels, both the factors namely, the spacing of humps and the intensity of flow play a combined role to bring down the mean speed.

A particular case of interest is the flow of 1500 vphpl. At this flow, the closest spacing in speed humps (5m) results in the highest fall in mean speed. Earlier, flow comparison for the same case showed that there was no difference between measured output flow and specified input flow. Every vehicle released into one end of the road reaches the other end, but with a reduced journey speed. This indicates that queues are formed to reduce the mean speed but not to an extent of affecting the number of vehicles completing the trip to the other end of the road.

For all flow levels simulated, reduction in speed improves as humps get closer. Vehicles continue to maintain a low speed after crossing the first hump, until they cross the second hump too. This is how the spacing of humps plays a role in reducing the overall mean speed.

3.3 Traffic Time Analysis

A decrease in speed apparently causes an increase in travel time. More insights can be drawn if travel times are also analyzed. Figure 5 provides a quantification of such increase in the travel time measured for the various combinations of hump spacing and flow levels simulated. For the base case with no speed humps, there is no notable change in travel time across different flow conditions. This shows that unless there is an obstruction, flow does not affect travel time for the cases simulated. As flow increases, notable increase in travel time is seen, especially when speed humps are present.

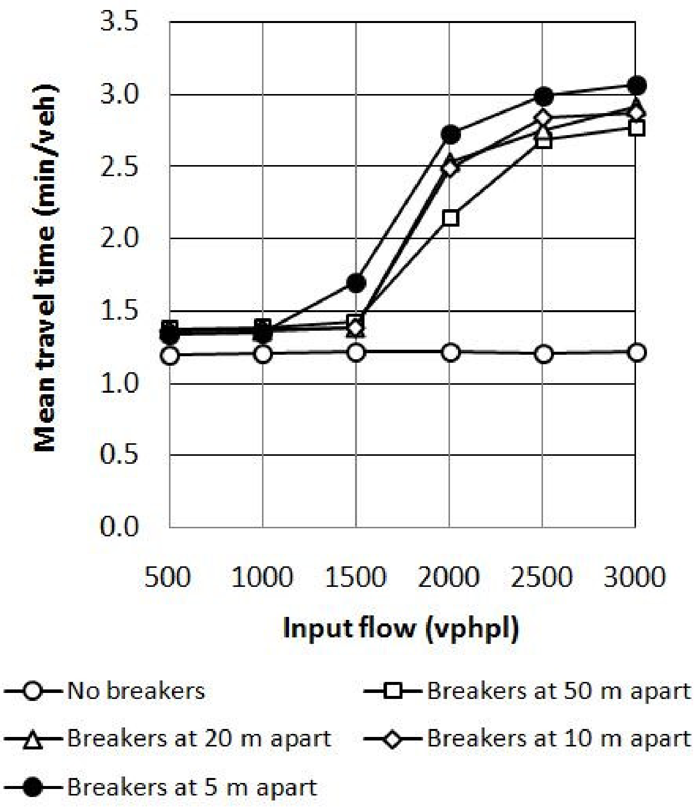

Figure 5. Effect of Speed Humps on Travel Time

The increase in travel time increases further at higher flows of 1500 and 2000 vphpl. This is the traffic condition where queues start building at speed humps. Spacing of humps affects travel time at high flows such as 2500 and 3000 vphpl causing a delay of more than 2 minutes per vehicle. This is significantly higher considering the fact that a vehicle never stops completely over a speed hump. Therefore, the increase in travel time must be attributed to time spent in slow moving queues. Speed hump acts like a bottleneck and causes stop-and-go situation for vehicles queued up-stream.

Every minute counts for an emergency vehicle such as an ambulance or fire truck that happens to pass through the street with speed humps. The increase in travel time shown in the Figure 5 can be avoided at least during vacation and holiday time if the speed humps are not present. In view of this, it is considered necessary to compare the percentage savings in travel time in the absence of speed humps.

3.4 Percent Savings Analysis

Removal of speed humps is expected to save travel time as travelers are ensured with an obstruction-free flow. The net percentage savings in travel time is shown in Figure 6. Every value in the Figure is percent savings in travel time for a particular flow and a particular spacing of speed humps. Three distinct levels of flow regions are observed. They are, low flow region of 500 and 1000 vphpl, transition flow region of 1500 and 2000 vphpl, and high flow region of 2500 and 3000 vphpl.

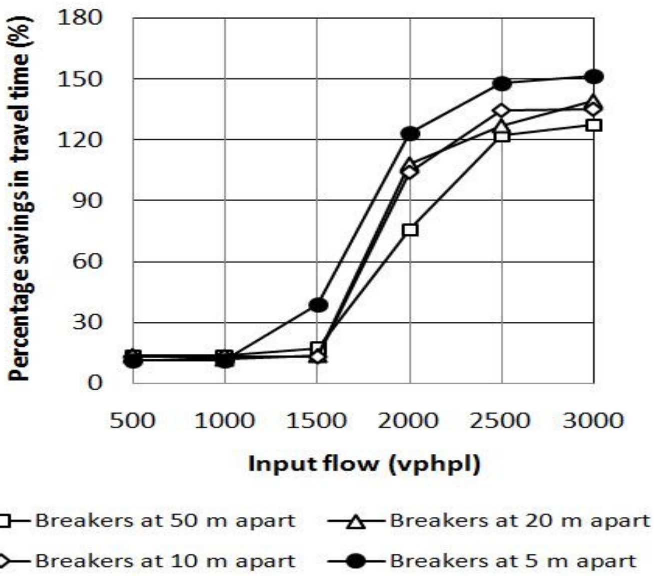

Figure 6. Savings in Travel Time under Hump-Free Condition

There is some level of travel time savings ensured in low flow region, irrespective the spacing between speed humps. This is important for streets where there is not much through traffic. Figure 6 shows around 10% of savings in travel time under low flow conditions. Every vehicle travelling on the street will get this minimum benefit when humps are removed.

Larger the number of vehicles provided with an obstruction-free flow condition, higher is the benefits that can be realized in speed and travel time. This is reflected in the results shown in the Figure 6. It is also evident that, shorter the spacing between humps, higher the benefits in the absence of such humps. The highest savings is achieved when removing speed humps that are closely spaced (5m). The benefit can be as high as 150% under high flow conditions. When humps spaced at 50m are removed, the resulting travel time savings are around 120%, provided the flows are higher.

Irrespective of hump spacing and flow conditions, a minimum percent savings in travel time of around 10% is ensured based on simulation results. When this is applied to millions of speed breakers at a national level (in India), for a period of one to two months of obstruction-free flow every year, benefits prove to be justifying enough to switch over to using portable speed breakers. This includes travel time savings for emergency vehicles like ambulances and fire trucks.

4. Conclusion

Speed humps are known to be effective in reducing the occurrences of accidents that might otherwise be resulted in speeding of vehicles. Educational institutions, especially schools offering primary and secondary education, essentially have at least two speed breakers on their approach streets. This is proven to ensure safety for students, staff and parents. However, many schools are closed for operation during long vacation or holiday period every year. In such period, if the street has a regular through traffic on it, then every vehicle needs to apply brake and slow down at the speed hump for no reason. Furthermore, speed humps are known to cause inconvenience to drivers, occasional injuries, increase in fuel consumption and pollution levels, and even damage pavements to certain extent. Besides providing an obstruction free travel, all the above ill effects can be avoided if speed humps are removed at least during schools' non-operational periods. This is possible only if portable speed breakers are used. In thickly populated country like India with millions of schools in its towns and cities, use of portable speed humps can be considered as time saving, fuel saving, emission preventing and pavement friendly alternative to permanent speed humps. The quantifiable benefits such as savings in travel time are measured by simulating both the absence and the presence of speed breakers. Different spacing values were used and different flow levels were simulated. The findings show that irrespective of the spacing of speed humps, there will be a definite savings in travel time in the absence of humps. These benefits are more pronounced if the flow levels are high. Therefore, the use of portable speed breakers prove to be worthy of consideration for school areas that might have no operation for a considerable period of time every year.

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