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SIDE FRICTION IMPACTS ON URBAN ROAD LINKS

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Abstract: Side friction factors are defined as all those actions related to the activities taking place by the sides of the road and sometimes within the road, which interfere with the traffic flow on the travelled way. They include but not limited to pedestrians, bicycles, non-motorised vehicles, parked and stopping vehicles. These factors are normally very frequent in densely populated areas in developing countries, while they are random and sparse in developed countries making it of less interest for research and consequently there is comparatively little literature about them. The objective of this thesis is to analyze the effect of these factors on traffic performance measures on urban roads.

To carry out this work, a research design was formulated including specific methods and prescribed limitations. An empirical case study methodology was adopted where Dar-es-salaam city in Tanzania was chosen as a representative case. The scope was limited to include only road-link facilities. A sample of these facilities including two-lane two-way and four-lane two-way roads were selected and studied. The study was conducted in two parts, of which each involved a distinctive approach. Part one involved a macroscopic approach where traffic and friction data were collected and analyzed at an aggregated level, whereas part two involved a microscopic approach where data of individual frictional elements were collected and analysed individually. Data collection was mainly performed by application of video method, which proved to be effective for simultaneous collection of traffic and side friction data. Data reduction was conducted chiefly by computer, using standard spreadsheet and statistical software packages, mainly SPSS and some computer macros.

Keywords: Motorised, friction, road.

I. INTRODUCTION

The urban transportation system is the engine of the economic activities in all-urban communities all over the world, and consequently sustains livelihood of the people living in them. Typical urban transportation facilities include railways, waterways, airways and roads. Among these, the big proportion consists of roads. Logically, most planning and research efforts have focused on the road system. In essence, road transportation system is the major player in the economic activities of most urban centers. In recent times, many cities have seen a large increase in road traffic and transport demand, which has consequently lead to deterioration in capacity and inefficient performance of traffic systems. In the past, it was thought that in order to resolve the capacity problem it was simply to provide additional road space. This was the main strategy applied in the U.S.A at the wake of 1960’s and 1970’s. A lesson learnt from this strategy is that adding capacity alone is ineffective because it induces travel growth that negates the benefits of highway expansion. Moreover, there is complexity in so doing for one reason that most cities are already built-up areas, hence it is difficult to carry out any substantial expansion works. In practice, it may be neither socially nor economically acceptable to balance supply and demand solely by increasing road capacity. Although the expansion of road infrastructure is not absolutely ruled out as the demand may be expected to continue to grow by time, the immediate, most relevant and acceptable strategy to mitigate capacity problems and increase efficiency of the road network is through traffic management applications. The most recent approach that has gained prominence in traffic management operations is the introduction of Intelligent Transportation Systems (ITS). Such technologies help to monitor and manage traffic flow, reduce congestion, provide alternate routes to travelers and increase safety. These systems have made significant success in major cities of many developed countries of America, Asia and Europe. For most cities of the developing countries, they have yet to realize these benefits, primarily due to economic and technological constraints.

On the other hand, the familiar tools (which are considered traditional) that are applied as traffic and demand management tools in order to increase the efficiency of the transport system include and not limited to: prioritization of road users (i.e. introduction of truck lanes, bicycle and pedestrian routes, peak lanes, etc.), road hierachisation (i.e. classification of road function), road markings and signs, enforcement devices (i.e. camera, police patrol, etc.), regulation of parking space, congestion charges, fuel prices, traffic restraints (i.e. limiting entry to city centre,

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Pedestrization of city centre, etc.), improvement of public transportation, etc. These tools are relatively cost-effective and technologically affordable and are applicable both in developing and developed countries. However, much as they may seem affordable, yet they are not effectively implemented in most developing countries. A good example is how traffic management is implemented by application of road hierarchy regulations. A hierarchical road network is essential to maximize road safety, amenity and legibility and to provide for all road users. Each class of road in the network serves a distinct set of functions and is designed accordingly. The design should convey to motorists the predominant function of the road. For example there is a broad division between arterial and non- arterial (or local) roads. Basically arterial and local roads make the backbone of most urban road networks. Arterial roads are important transport routes that are designed for high traffic volumes and high speeds (i.e. through traffic movement), whereas local roads are essentially intended for accessibility (low volumes and low speeds). Nevertheless, far from this conception, many arterial roads in many developing countries exhibit deteriorated capacity and poor performance.

Various studies have studied this problem in some developing countries and established that among other things, there is often a great deal of activity on and alongside these roads, which affects the way in which they operate. This interference to the smooth flow of traffic is known as "side friction". In traffic engineering practice, classification of roads by "environmental" class is often used as proxy for the effects of side friction, such as residential, shopping, rural, suburban, urban and so on. Traffic activities such as number of turning vehicles, parking, pedestrian activity and so on are used for this purpose also and separate speed-flow curves or capacities are commonly given for each class. When mobility is a priority, road links are usually described in terms of speed-flow relationships, which describe their functionality in terms of the main operational characteristics namely, free-flow speed and capacity. From the empirical studies such as those used in the Highway Capacity Manual (HCM 2000) it is known that various factors including roadside activities reduce capacity and affect speed-flow relationships. By implication if these activities are adequately addressed and managed, capacity and performance could be improved and greater economic benefits could result from such policies.

II. MATERIALS AND METHODS

Though it is widely appreciated that activities at the roadside affect the operation of the traffic stream and may cause delay, there are few references which try to quantify their effects directly especially for developing countries where their effects are likely to be high. The most usual way in which such effects are incorporated into traffic calculations and procedures is by some kind of proxy classification. Perhaps the most well known set of procedures for capacity and level of service (LOS) calculations are applied in the U.S. Highway Capacity Manual (HCM 2000), which uses various proxies that are described below.

It is clear that the HCM 2000 considers the roadside environment and consequent friction to traffic to be important, as they and their effects are discussed in general terms in several parts of the manual, for example it is acknowledged that the 'development environment has been found to affect the performance of multilane highways'. These effects are generally incorporated intuitively in the classification system used for highways. The effects of friction are not explicitly quantified or directly referenced. However, the manual deals with roadside environment indirectly by classification of different facilities as follows:
For 'basic freeway segments' free flow speed (FFV) is adjusted downwards if shoulder lateral clearance reduces from the base value of 1.8 m. This implies that if objects exist at the roadside or on the median closer than 1.8m from the road edge the lateral clearance is reduced. The adjustment factors are shown in Table 2.1. It can be seen that the maximum lateral clearance effect is represented by an adjustment factor of 8.7 km/hr (reduction in FFS) for standard lanes with an obstruction at the carriageway edge of a four-lane (dual two-lane) freeway.

Table 1 Adjustment for lateral clearance (Source: HCM 2000 exhibit 21-5) Four-Lane Highways		Six-Lane Highways	
Total Lateral Clearance[a] (m)	Reduction in FFS (km/hr)	Total Lateral Clearance[a] (m)	Reduction in FFV (km/hr)
3.6	0.0	3.6	0.0
3.0	0.6	3.0	0.6
2.4	1.5	2.4	1.5
1.8	2.1	1.8	2.1
1.2	3.0	1.2	2.7
0.6	5.8	0.6	4.5
0.0	8.7	0.0	6.3

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a: *Total lateral clearance is the sum of the lateral clearances of the median (if grater than 1.8 m, use 1.8 m) and shoulder (if greater than 1.8 m, use 1.8 m). Therefore, for purposes of analysis, total lateral clearance cannot exceed 3.6 m.*

Certain types of obstructions i.e. high-type median barriers in particular, do not cause any deleterious effect on traffic flow. Judgment should be exercised in applying these factors (HCM 2000).

For multilane highways (defined as those with a signal spacing of less than two miles or three km), the HCM 2000 identifies the following 'frictional' effects:

1. Vehicles enter and leave roadside premises and minor roads. The effect is greater if the vehicles are left turning (USA).
2. The 'friction' with opposing traffic reduces speed.
3. The 'visual impact' of frontage development influences driver behaviour

The HCM 2000 also notes that the amount of interference with traffic varies widely according to the 'development environment', meaning the type and density of land use development. This is dealt with very simply by categorizing the facility as being 'rural', 'low-density suburban' or 'high-density suburban'. No further quantification or discussion is presented and no direct references are given.

For urban and suburban arterials (those with signals less than two miles apart) the HCM 2000 recognizes that roadside development may be intense and can produce 'frictions' which limit drivers' choice of speed. Parking, pedestrian movement and 'city population' are specifically identified as affecting performance. Frictional effects are dealt with by firstly classifying the arterials by functional class, as follows:

- Principal arterials (for major intra-urban movements), and
- Minor arterials (linking principal arterials).

Secondly, within each functional class the arterial is assigned to a design category, as follows:

- High speed design (very low density of access points, signals and roadside development)
- Suburban design (low density of access points, signals, and 'low-to-medium' roadside development.
- Intermediate design (moderate density of access points and signals, and 'medium to moderate' roadside development, and some roadside parking)
- Urban design (High density of access points, significant roadside parking and high density of roadside development)

This classification indirectly incorporates the effects of friction, through the degree of access control and level of frontage development.

There are several other studies identified to have attempted to incorporate and quantify the effects of different frictional elements on road networks of urban areas. Among these, the most comprehensive was the one conducted in the course of implementing the Indonesian Highway Capacity Manual (IHCM) and reported by Bang et al. (1995). This study was carried out as an Indonesian Capacity Manual Project, under the consultancy of Swedish National Road Consulting AB, SweRoad. It identified significant effects of geometric factors (i.e. carriageway width, shoulder width, median), traffic and environmental factors (directional split, city size) and side friction factors (i.e. pedestrians, non-motorized vehicles, public transport vehicles) on speed-flow relationships on Indonesian urban/suburban road links. Road links was only part of the large study that involved all other facilities namely; intersections, roundabouts and weaving sections. This project was conducted as an empirical study where three principal items were measured; speed, traffic flow and traffic composition. Other data that were recorded are side friction, geometric and traffic control conditions.

Effect of side friction:

To demonstrate the effect of side friction, a number of items were measured. These included three types of data:

i. Blockage of the travelled way included: Slow moving objects (i.e. pedestrians crossing or walking along, non-motorized vehicles), parked vehicles, public transit stops, spilled load, and road works.
ii. Shoulder activities included: food stalls, vendors, pedestrians, parked vehicles.
iii. Roadside accesses included: location and use of exits and entrances from all roadside premises e.g. service stations, houses, parking lots, etc.

Non-parametric correlation analysis was used to identify, for each site separately, those items of friction that were significantly correlated (α = 0.05, 1 tailed) with mean 15-minute two-way speeds. Only four frictional items were

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judged, on the basis of the correlation analysis, to be generally important at most sites. These were; pedestrians walking along the road (ped/hr), pedestrians crossing the road (ped/hr/km), stopping minibuses on the roadway (veh/hr/km) and exit/entry vehicles (veh/hr/km). The effect of the above factors on the speed-flow models of the different road types was investigated. Since the units were not the same for the different friction factors, they were combined using a ranking process which enabled to express them using one unit coded 'FRIC'. To demonstrate the effect of the combined factors, speed-flow relationships were plotted in situations when their intensity was low, medium and high. Figure 2.6 below shows the effect of these three different situations.

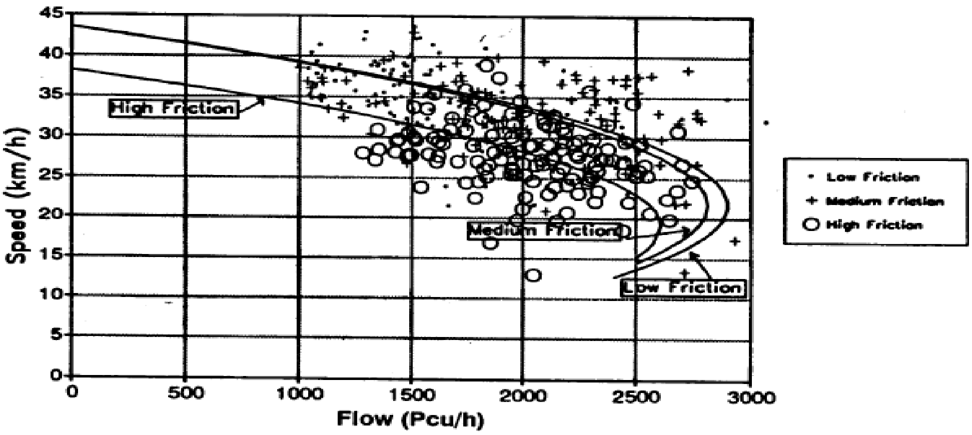

Figure 1 Effect of side friction on 'speed-flow relationships' of 2-lane 2-way Indonesian roads.

III. RESULTS AND DISCUSSION

Geometric characteristics.
Geometric measurements were obtained in the field by means of a tape measure. The degree of accuracy was normally to the nearest 10cm. The data were recorded on a sketch drawing.

• Side friction
Since there are no standard approaches to measurement of side friction, a great deal of experimentation was carried out as described below:
i. Stationary manual observation: Stationary observation was the most preferred method, either using surveyors in the field, or by means of video recording and later observe in the laboratory. The observations were continuous and covered all the studied section.
ii. Mobile observation:

Consideration was given to using mobile observation by means of a floating car or patrolling observers, who would note frictional items when they encounter them. Floating car is essentially a moving car, which uses an in-vehicle video camcorder to record friction events as it moves along.
However, in the end it was decided to use stationary observers because the studied segments were short enough (approximately 200m) to be observed by a stationery observer. According to this method, side friction was recorded simultaneously with the video recording, separately for each side of the four-lane two-way roads and for both sides for two-lane two-way roads with one surveyor taking manual recordings. The items of side friction recorded by the surveyor were the following:
i. Parked/stopping vehicles (by type) for a specified time interval (preferably five minutes intervals), (Parked vehicle means the vehicle is not moving for much longer time, while stopped vehicle means the vehicle is temporarily not moving probably for just few seconds loading or off-loading)
ii. Pedestrians crossing the road or walking along during the same time intervals
iii. Bicycles along the shoulders or in the travelled way (bicycles are separated from the non-motorized vehicles because of their very different characteristics from the others, and they form a larger group of their own)
iv. Non-motorized vehicles along the shoulders or in the travelled way (these essentially included slow moving vehicles such as push-carts and three wheeled bicycles, which are common in the study area)

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Examples of the above mentioned frictional items are shown in figure 2 below:

TYPES OF SIDE FRICTION FACTORS			
Pedestrians	Bicycles	Stopped or parked vehicles	Non-motorized vehicles
			

Figure 21 Typical side friction factors observed in the field.

Simultaneous measurement of speed, flow and side friction.

It was necessary to carry out simultaneous measurements of several variables for effective application of the selected methods. As described above the main methods applied to carry out the basic measurements of speed, flow and side friction were based on video and manual observation over a long base study segment/section. Essentially, speed and flow were measured by the video method, whereas both video and manual surveyors recorded side friction events. The long base study section was defined with the following characteristics:
i. More or equal to 200m long.
ii. Free from congestion (upstream) and platooning (downstream) effects of intersections
The survey was set up as shown in figure 4.2 below.

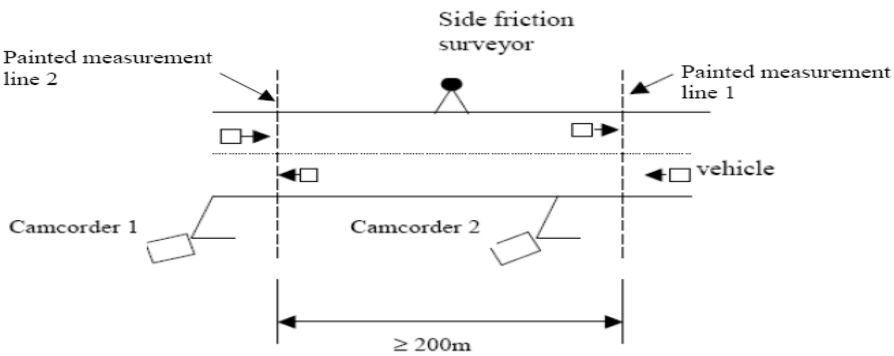

Figure 3 Method for road link surveys (2lane-2way roads)

IV. CONCLUSION

This thesis has been concerned with the concepts, theories, and methods related to side friction impact on performance and capacity of urban road links, and was performed in Dar-es-salaam as a case study. A major part of this work has focused on issues related to identification of side friction factors and application of various measurement methods and analysis techniques used for determining their impact on speed and capacity at an aggregated level (macroscopic) and at an individual level (microscopic). On the basis of the macroscopic study, modelling based on regression analysis was performed for this purpose. Analysis of individual friction factors per se is quite rare in the prevailing research literature: On this basis the microscopic study was performed where measuring and evaluation methods were devised with a view to obtaining important knowledge concerning their potential impact on speed. Generally, the study was performed in two parts based on these two methods of approach (macroscopic and microscopic). Both parts were related in terms of objectivity and only differed in approach and detail. They both focused on attaining the prescribed objectives, which were addressed by the two methods as follows:
1. To assess the impact of side friction on speed and capacity of urban road links. This was the primary objective and was addressed by both methods.

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2. To develop simplified procedures for taking account of side friction in capacity calculations: This was addressed by macroscopic approach.
3. To develop simplified procedures for taking account of the effect of individual side friction components on speed: This was addressed by microscopic approach
4. To identify other important factors affecting performance and capacity of different types of road links: This was addressed by macroscopic approach.
5. To develop survey methods for simultaneous collection of data on speeds, flows and side friction: This was addressed by both methods.

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