EXISTING STATUS OF HANOI URBAN TRANSPORT AND SOLUTIONS IN TERM OF PRODUCTIVITY AND SAFETY

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abstract: In recent years, major cities in Vietnam have underdone periods of rapid development and growth driven by restructuring of the economy in which transport is not exception. The number of vehicle has been increasing in accordance with travel demand causing chaotic mixed traffic in Hanoi that creates traffic congestion, accidents, air and noise pollution looming large.
This paper focuses on analysis of existing traffic situation and safety in Hanoi and proposes a solution in geometric design and traffic control design for urban road to enhance mobility in term of productivity and to ensure the traffic safety. A specific section of a road in Hanoi will be taken into consideration as an example.

I. INTRODUCTION

In recent years, major cities in Vietnam have underdone periods of rapid development and growth driven by restructuring of the economy. This trend is likely to continue and accelerate. In order that economic activity can be sustained and the urban environment protected, there is a pressing need to develop and introduce traffic management measures to maximize the potential of the transport system.

This study focuses on existing situation of Hanoi urban transport and one solution of geometric for urban road to enhance mobility in term of productivity and to ensure the traffic safety.

2. PROBLEM STATEMENT AND ANALYSIS OF HANOI URBAN TRAFFIC

2.1. Main data on Hanoi Urban Transport.

- Population: 3,057,000 people, included more than 1 million in urban area;
- Total area : 2,139 km^2, included 40 km^2 of urban area;
- There are 340 streets and roads in the inner area with total length of around 200 km, the average road length is 500-600m
- Road density in urban area 5km/km^2, 0.2 Km/1000 inhabitants
- Most roads are narrow (88% less than 14 m wide)
- There is main railway line with total length of 12 km crossing the city with 8 main at-grade junctions and 30 train pairs running a day.
- There are 60,000 cars (predicted growth rate 10 – 15%), 650,000 motorbikes (growth rate 20-24%) and more than 1 million bicycles cruising the streets.

- Average travel speed of motorized vehicles : 15 kph; average travel speed of non-motorized vehicles: 6 kph
- There are only 115 of 580 intersections are erected with traffic lights.
- Number of accidents: 670 – 800 /year killing 300-350 people.
- 50% accidents caused by motorbikes, 30 % by cars, truck and buses.
- Accidents happening at intersections occupy 42.1 – 48.5 % of total accidents in the city.

Table 1: number of motorized vehicles registered in recent years in Hanoi

Year	Automobile (veh.)	Motorcycle (veh.)
1990	34322	195447
1991	42318	240225
1992	45364	273663
1993	49006	346977
1994	52535	420353
1995	60231	498468
1996	70880	570544
1997	86436	626565
6/1998	88876	670025

Because of low density and narrow width of roads, many roads are overloaded with very high density of motorcycles and cycles. At present, travel demand for using motorcycles and cycles occupies 87% while only 3% for buses and cars.

Since early 1990's, passenger transportation taken by public transport has been reduced with the time. While the urban population is getting higher leading to the rapid demand for travel, the number of buses is decreasing. The tram line had stopped operating for many years. The passenger transport mostly relies on two-wheel vehicles.

Table 2: Proportion of vehicle and passenger distributed by transport mode in Hanoi

Mode	Vehicle (%)	Passenger (%)
Cycle	35	29
Motorcycle	59	58
car	4	8
Bus	1	4
Others	1	1

One of the reasons for ineffectiveness bus service is the shortness and narrowness of roads. Besides, no exclusive bus lane makes bus operation difficult. Due to the fact that the number of bus route is small serving in limit area with bus stops placed far from resident areas, there is almost no connection between routes, the quality of bus service does not satisfy with the demand such as low frequency, no timetable, long waiting time, low convenience and security, bus service has still not attracted passengers. Bus service neither keeps its own nor attracts more new passengers.

Although the number of car is still small and much lower in comparison with cities of the same size and importance in the region, it is a great concern that the growth rate of this kind of vehicle has been continuously increasing.

Motorcycles and bicycles provide a uniquely economical and affordable means of transport which is favored by the majority of the country's urban population. Continued reliance on these modes eases the Government's financial burden associated with the provision of public transport. In parallel with the mobility and freedom of movement offered by the private modes, the chaotic current mix of non-motorized traffic, mostly bicycle, and motorized traffic, of four wheel and two wheel modes on the most roads, causes a speed reduction for 4 wheel vehicles (10km/hour in rush hours) and safety problems for non-motorized traffic. High proportion of motorcycles requires good organization not only in term of parking place but also of traffic control. Even in some signalized intersections, the police controls still are needed at peak hours.

walk-sides are often occupied by parking motorcycles, sellers, vendors so that the vehicle lanes are occupied by pedestrians, vendors in many places. The roads are narrow becoming narrower.

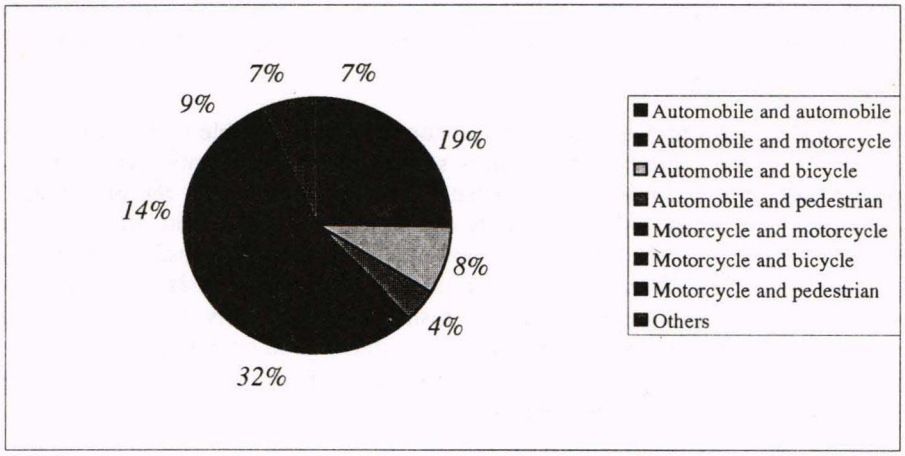
Without medians in most roads, in Hanoi streets, pedestrians across where and whenever they can, cyclists and motorists also make U turn at any time. Road users often use wrong lane intentionally or do not give way for others. All these contribute to the limitation of vehicle speed . Most accidents happen between motorcycles and motorcycles, motorcycles and cycles, cars and bus with motorcycles and cycles, motorized vehicle with pedestrians. Proportion of traffic accidents concerning to motorcycles is 73.08%; automobiles 38.7%; bicycles 22.4%; pedestrian 12.49%.

Table 3: Proportion Traffic Accidents happen in main streets of Hanoi distributed by vehicle mode

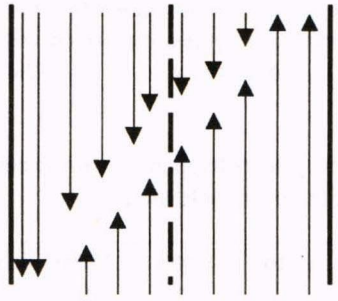
Year	Auto. and Auto.	Auto. and Motor.	Auto. and Cycle	Auto. and Pedes.	Motor. and Motor.	Motor. and Cycle	Motor. and Pedes.	Others
1995	9.1	18.2	13.64	4.55	31.77	13.64	4.55	4.55
1996	5.58	16.69	5.88	3.92	31.36	12.75	11.76	11.76
1997	7.58	21.16	7.58	3.03	31.85	15.16	9.09	4.55

Table 4: Average proportion traffic accidents in Hanoi road network in 3 years

Between mode	Proportion (%)
Automobile and automobile	6.88
Automobile and motorcycle	18.60
Automobile and bicycle	8.48
Automobile and pedestrian	4.22
Motorcycle and motorcycle	31.34
Motorcycle and bicycle	14.41
Motorcycle and pedestrian	9.31
Others	7.04



Because of no traffic light in many intersections, traffic jams occurs very often in peak hours. When congestion happening in uniform sections, intersections or at crossing between roads and railways, it takes a long time to release due to the fact that vehicles of one direction occupy the reserved lane of the other direction, the section turns out to be bottleneck. This can be shown in following figure:



This problem also leads to the increasing of delay in average travel speed. It can be said that bicycles and pedestrians are impedance of motorized vehicle, and pedestrians, bicycles and motorcycles are impedance of automobiles.

Accidents causing personal injuries or fatalities to cyclists and motorists and pedestrians in urban Hanoi can be defined in following main reasons:

i) In uniform sections

- Accidents occur in uniform sections when pedestrians across the streets, cyclists and motorists make U turn (suddenly left turning) for certain reasons like going home, shopping, meeting friends etc.
- Head-on collisions between vehicles occur mainly due to no medians between two directions
- Fatal accidents where slow vehicles such as bicycles have been hit from behind due to there is no separation between non-motorized and motorized traffic.

- Accidents happened when cars overtake motorcycles, cycles; motorcycles overtake cycles and even car also due to no separation between non-motorized and motorized traffic.

ii) In intersections

- Accidents with cyclists and motorists approaching from the right: because of no traffic signal or they did not perceive traffic adequately as they failed lowering their speed when emerging from side streets or entrances with poor visibility conditions.
- Accidents with cyclists and motorists approaching from the left: because of no traffic signal or of vehicles' running against the red light, the negligence of the give-way line.
- Accidents with left turning cyclists and motorists in front of oncoming counterparts due to the roads are narrow, there is no traffic lights or the cyclists and motorists neglect their duty to wait for traffic before turning left.
- Accidents with left turning cyclists and motorists in front of counterparts from the same direction due to there is no left-turn lane or no attention to traffic of the cyclists and motorists.
- Accidents with left turning counterparts in front of oncoming cyclists and motorists due to there is no traffic signal or they do not perceive well the presence of vehicles.
- Accidents happen with right turning counterparts in front of cyclists and motorists from the same direction.

iii) In crossings between roads and railway

- Accidents happen with pedestrians and cyclists who try to pass the safety barriers for railways when trains crossing the city.
- Accidents happen with people occupying railway's right – of – way for selling goods due to there is no separated guardrail in many sections.

The chaotic mixed traffic with overcrowded motorcycles also affects seriously urban environment like air pollution and noise pollution. This paper emphasizes only the concept of productivity and safety.

3. PRODUCTIVITY

In this study, productivity is defined as the total throughput or passenger-kilometers of travel time in one hour under the prevailing conditions on a route. The productivity is measured in person-km/hour and expressed mathematically as:

$$PRODUCTIVITY = \sum_w \sum_m PASFLOW^w_m * TS^w_m$$

This equation indicates that it is simply a measure which combines quantity and quality of person flow on a route.

Where:

$PASFLOW^w_m$ = Flow rate of passenger of mode m under the prevailing geometric and control conditions on segment w. It is basically the volume of persons serviced in one hour.

$PASFLOW^{w}_{m} = VEHFLOW^{w}_{m} * OCC_{m}$

$VEHFLOW^{w}_{m}$ = Flow rate of vehicle type m under the prevailing geometric and control conditions on segment w. It is the volume of vehicle in one hour.

OCC_{m} = Person occupancy of each vehicle of mode m

TS^{w}_{m} = Average travel speed of mode m under the prevailing geometric and control and flow conditions on segments w

From the equation we see that productivity depends on type of vehicles, occupancy of passenger of vehicle and especially the average travel speed of vehicles. Using vehicle with high person occupancy like bus, minibus is one of the alternatives. This alternative requires the encouragement of people to use public transport and public transport itself has to improve its service to attract passengers. In this study, let us focus on the improvement of geometric design and traffic system traffic system to increase the average travel speed of vehicles

4. SAFETY

Human error is the underlying cause of almost all accidents. The estimated in this regard leads to the conclusion that with over 90% of accidents. But a small proportion of accidents could also be attributable to vehicle defects or faults in road design. Often and unfairly, the resultant conclusion is that road accidents can only be prevented through education, information and police enforcement. Such a conclusion ignores the true cause of accidents. And these true caused are rooted in the present road traffic system, a system which leaves room for human error. Modern traffic confronts the road user with a series of relatively unpredictable road and traffic situations. The present system makes it difficult for road users to recognize danger and demands a great deal of skill if conflict is to be avoided.

The police report on this accident is likely to have stated that the driver lost control over the steering wheel and was probably driving too fast, thereby resolving the legal question of blame. But example also illustrates that there are many more factors at play, and that there are many more ways of preventing this type of accident, rather than simply pointing out people's deficiencies and then punishing them for consequences.

5. CHARACTERISTIC OF STUDY ROAD SECTION

The study road section names Giang Vo street located in the west of the city. Its characteristics are described in terms of following 3 components:

1. Geometric characteristics;
2. Traffic flow characteristics; and
3. Control characteristics and safety problem.

5.1. Geometric characteristics

The road section is two way roads as showing in attaching figure. At present, the condition of the road is considered to be good. One side of the segment is a zoo, the other side is houses, shops. The geometric characteristics can be described as follows:

- Length of the segment : 900 m
- Width of carriageway : 15 m
- Width of walkside : 4 m in the zoo side
  3 m in the other side
- No median
- No separation of lanes.

At B the road is separated into NgocKhanh street and GiangVo street creating Y intersection called VoiPhuc Intersection.

5.2. Flow characteristics.

This segment is two way traffic segment without median and separation between lanes. Chaotic mix traffic including bus, car, motorbikes, bikes sharing the same lane causes the reduction of running speeds of vehicles: bicycles 6 kph; motorcycles and other motorized vehicles15 kph, even 10 Km/hr at rush hour.

The traffic volume in this segment is not considered very high, however, as mentioned above, mix traffic is serious problem for congestion, low speed and safety problem.

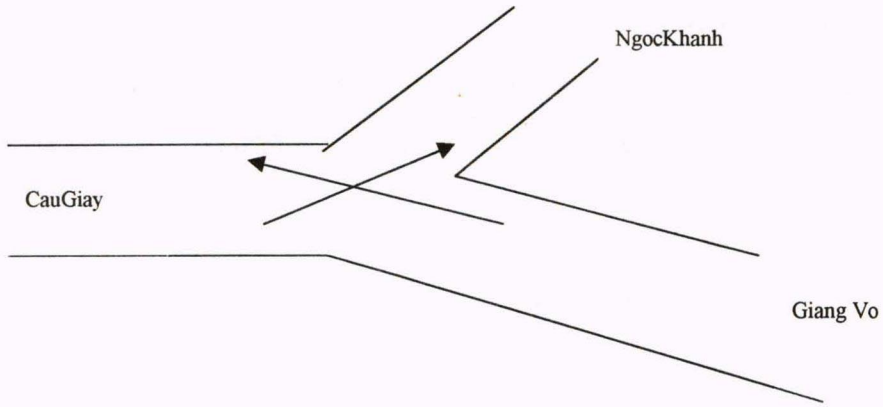
The pedestrian proportion in this segment is very few so the width of the walk-sides satisfies the demand although now, the walk-sides here are occupied by the vendors and motorist parking.

Table 5: The vehicle volume (AADT) by type of vehicles

segment	car	truck	bus	mini-bus	motorcycle	cycle	total (veh)
CauGiay - Giangvo	1367	500	354	533	37527	25826	66107
Giangvo-CauGiay	1367	500	354	533	39520	29213	71487

5.3. Control characteristics and safety problem.

Voiphuc intersection is uncontrolled. A lot of accidents happen at Voiphuc intersection. Most accidents caused by motorcycles. Fatalities are cyclists and motorists. Small proportion of accidents caused by buses and cars. The reason of accidents are often the conflict between movement Caugiay to NgocKhanh and from Giang Vo to CauGiay as showing in following figure:



5.4. Determine current capacity and productivity

Capacity of a segment can be calculated by following formula:

$VCAP = IVCAP * f_t * f_w$

For intersections, because at present, there is no control devices we assume the capacity is equal to capacity of a segment.

Where:

IVCAP = ideal vehicular traffic capacity of a lane = 1800 pcphpl

f_t: Adjustment factor for mixed traffic conditions:

$$f_t = 1/\{ 1 + \Sigma [PF_m * (PCE_m - 1)]\}$$

f_w: Adjustment factor for non-standard width of lane and can be obtained from following table

Table 6 : Adjustment factor

Lane width		f_w
(feet)	(meter)	
8	2.44	0.867
9	2.74	0.900
10	3.05	0.933
11	3.35	0.967
12	3.66	1.000
13	3.96	1.003
14	4.27	1.067
15	4.57	1.100
16	4.88	1.133

If $W \geq 8$ $f_t = 1 + (W-12)/30$

PCE for mixed stream is calculating by following formula:

$$PCE_x = 0.4 [(U_{0car}/U_{0x})*(L_{eff.x}/L_{eff.car}) + 1] \quad \text{if } U_{0car}/U_{0x} < 2$$

Otherwise:

$$PCE_x = 0.4\ [(U_{0car}/U_{0x})*(L_{eff.x}/L_{eff.car}) + 1]^{1+2.5\,p^2}$$

Where

U_{0car}, $L_{eff.car}$ = free-flow speed and effective length of car respectively

$L_{eff.car}$, $L_{eff.x}$ = free-flow speed and effective length of vehicle type x respectively

As mentioned above, the productivity is determined by following formula:

$$PRODUCTIVITY = \sum_w \sum_m PASFLOW^w{}_m * TS^w{}_m.$$
$$= \sum_w VEHFLOW * \sum_m PF_m * OCC_m * TS^w{}_m$$

Where
$\sum_m PF_m * OCC_m$= Average occupancy
$TS^w{}_m$ = Length of the segment / RT + DY
RT = Running time in the segment
RT = Length of the segment / RS
RS = Running speed of vehicle in the segment. According to greenshield:
$RS = U_o/2 * [1 + (1 - 4q/K_jU_o)^{1/2}]$
K_j = Jam density = $1000/(\Sigma\ PF_m * L_{eff(m)})$
DY = Delay, for unsignalized intersection
$DY = e^{3.8\ V/c}$
Since the width of the lane is 7.5 m we will consider two lanes
From table $F_w = 1$
Results of calculation is showing in following tables:

Table 6: Current productivity Cau Giay - Giang Vo

item	car	truck	bus	mini-bus	motorcycle	cycle	Total	pcph
Flow rate	71	26	18	28	1955	1345	3443	3302
PF	0.020678	0.007563	0.005354	0.008062	0.567670	0.390669	1	
Uo	60	40	40	45	40	20		
PF/Uo	3.44643E	1.89087E	1.33874E	1.79171E	0.014191	0.019533	0.03457202	
PCE	1	1.225	1.225	1.066666	0.775	1.212990		
PF*PCE	0.020678	0.009265	0.006559	0.008600	0.439944	0.473878	0.95892734	
OCC	2.2	1	40	12	1.5	1.2		
PF*OCC	0.045492	0.007563	0.214198	0.096752	0.851505	0.468803	1.68431633	
Leff	8	11	11	10	5	5		
PF*Leff	0.165428	0.083198	0.058904	0.080626	2.838352	1.953348	5.17985992	

Uomix=	28.92512	kph	
Kjam=	193.0554	vpk	
Ft=	1.042831		
Capacity=	3754	pcph	
v/c	0.879458		
DY=	28.27394	sec	= 0.007853h
RS=	23.70893	kph	
RT=	0.037960	h	
TS=	19.64454	kph	
Product=	113923	passkmph	

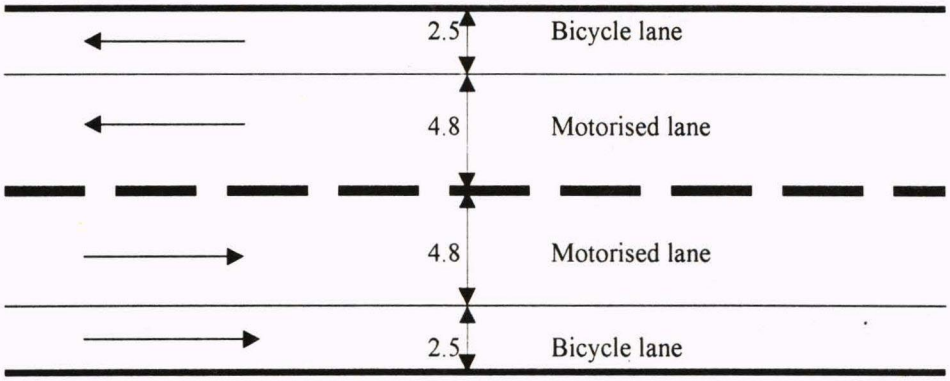
Reality is much more complicated. Because of chaotic mixed traffic and no traffic control devices at intersection, apart from that the carriageway is often occupied by people, the delay should be much higher than calculation. Conflicts between vehicles especially at intersection are the reason for a lot of accidents.
Two alternatives are taken into consideration as follows:

- Separation of motorised and non-motorised vehicles to improve traffic productivity and safety
- Installing traffic control system at intersection for the purpose of safety

6.1 Separation of motorised and non-motorised vehicles.

Since the traffic flow in this segment is quite crowded so for the aim of safety, firstly, there should be raised median to prevents the vehicles from the head-on collision, making U turn and crossing the road.

The separation can be made as follows:



From table
Bicycle lane : $f_w = 0.9$
Motorised lane : $f_t = 1.133$.
PCEs of motorised vehicle are calculated by above mentioned formula
PCE of bicycle = 0.3
The results of calculation of capacity, productivity are showing in following table:

Table 7: Improved Productivity of segment

item	car	truck	bus	mini-bus	motorcycle	Total	pcph	cycle	pcph
Flow rate	71	26	18	28	1955	2098	1648	1345	404
PF	0.033841	0.012392	0.008579	0.013346	0.931839	1		1	
Uo	60	40	40	45	40			20	
PF/Uo	5.64029E	3.09819E	2.14490E	2.96579E	0.023295	0.024680		0.05	
PCE	1	1.225	1.225	1.06667	0.775			0.3	
PF*PCE	0.033841	0.015181	0.010510	0.014235	0.722175	0.795944		0.3	
OCC	2.2	1	40	12	1.5			1.2	
PF*OCC	0.074451	0.012392	0.343183	0.160152	1.397759	1.987940		1.2	
Leff	8	11	11	10	5			5	
PF*Leff	0.270734	0.136320	0.094375	0.133460	4.659199	5.294089		5	

Uomix=	40.51713	kph	
Kjam=	188.8898	vpk	
Ft=	1.256368		
Capacity=	2562	pcph	
v/c	0.643125		
DY=	11.51761	sec	0.003199h
RS=	38.20414	kph	
RT=	0.023557	h	
TS=	33.63606	kph	
Product=	140286	passkmph	

Uomix=	20	kph
Kjam=	200	vpk
Ft=	1	
Capacity=	1620	pcph
v/c	0.2490740	
DY=	2.5766277	sec
RS=	19.482220	kph
RT=	0.0461959	h
TS=	19.184980	kph
Product=	30965	passkmph

Total productivity = 171250 passkmph

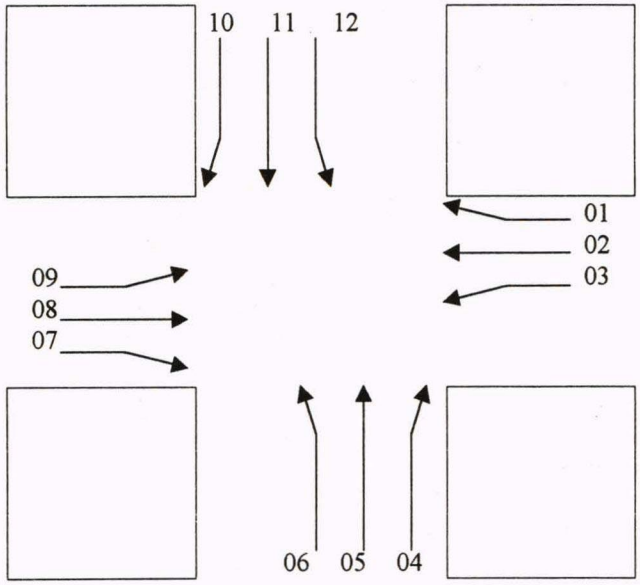
Comparison with existing condition, we have following table:

Productivity			
segment	Existing	separation	improve
Cau Giay - Giang Vo	113923	171250	50.32083

6.2. Installing traffic control system for intersections for purpose of safety

As mentioned above, most accidents happen at intersections so a part from separation of traffic lanes it is necessary to apply traffic control system to reduce conflicts at intersection for ensuring the safety.

Like pedestrians, the capacity to handle bicycle at intersection is huge and there is a exclusive lane for bicycle, let us take the motorised vehicles into consideration only. All kind of motorised vehicles will be converted into cars by PCE described before. Codes for traffic stream are as follows:



The optimal cycle time is calculated by following formula:

$$TC = (1.5*TLI+5)/(1-\Sigma v_i/s_i)$$

Where:
v_i= adjusted flow rate for lane group i
s_i = saturation flow rate for lane group i
TLI = internal lost time per cycle = change lost time + start-up lost time.
The length of the cycle should be greater than 65 seconds and smaller than 120 seconds.

Shared lane may be used by both left-turning and through-going vehicles. If the number of left-turn vehicle dominates the exclusive left-turn lane is needed. This can be done by converting the left-turn flow rate to equivalent flow of through vehicles:

$$V_{mlte} = V_{mlt}*1800/(1400-V_o)$$

Where:
V_{mlte} : Equivalent left-turn flow rate
V_{mlt}: Flow rate of left-turn movement
V_o: Flow rate of opposing movements

If V_o is equal or greater than 1400, A protected exclusive left-turn lane is necessary.
If $V_{mlte} > (Va - V_{mlt})/(N-1)$ the lanes should be divided into two lane groups
V_a = Flow rate approach.

Applying this we can calculated the suitable cycle time and green time for each direction. For this intersection there should be two left turn lanes (09) to ensure that the intersection can be handled. Due to the limitation of the paper content, the specific calculation could not be present here.

CONCLUSION AND RECOMMENDATION

With the spectre of traffic jams, accidents, air and noise pollution looming large, the current public transport system meets the need of a very small percentage of the population, forcing people to find private means like motorcycles and cars.

Productivity is a criterion to measure the quantity and quality of person flow on a route. Reducing the speed differences between vehicles by separation traffic streams can not only increase the productivity but also reduce safety problem.

Due to the fact that most accidents occur at intersections because of the chaos of turning left, turning right and going through, the traffic control devices are necessary to handle traffic stream at intersections.

Rapid population growth and economic development are challenging transport authorities to find long-term solutions for the city's public transport system.

Bicycles provide a flexible, economical and affordable mean of transport for short distance without polluting environment that should be encouraged to use. For this aim, the cycle paths should be built in future.

The enforcement of traffic regulations is very important. The aim of improvement of traffic productivity and safety can only gain with the combination between good road facilities and well-regulated traffic system.

A specific study for road section from CauGiay to Giang Vo in term of productivity and traffic safety was made. The study shows that the productivity is improved considerably after applying separation of non-motorized vehicles from motorized vehicles. The problem of conflicts at intersections was solved by traffic control design depending on the traffic demand.

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