SOLUTIONS FOR MIXED VEHICLE FLOW FOR BUOI INTERSECTION PROJECT IN HANOI

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Abstract:

Buoi intersection is one of key intersections to be given priority to build in order to preventing traffic in North-West Hanoi from congestion.

The paper presents an overview of existing status of Hanoi urban traffic and transportation development plan of Hanoi up to the year 2020, describes briefly the traffic survey and data collecting process so as to propose technical solutions for designing Buoi intersection suitable with Vietnam condition - mixed traffic flow.

I. EXISTING STATUS AND INTERSECTION.

1.1. Existing Status of Hanoi Urban Traffic and Buoi Intersection in Brief.

Hanoi is the most important junction of Vietnam, where all kinds of transport modes like road, railway, river waterway and airway converge. Hanoi transport system has been paid great attention to develop in recent years.

Many Hanoi radial roads like strategic routes Highway No.1A, No.5, No.6, No.32, No.2, No.3, No.18 have been built, the inner road network has been rehabilitated and improved too. Some roads have been extended or renewed the pavement and walk-side, traffic control and management has been also enhanced that remarkably improves the traffic quality of the city.

However, the existing road traffic is far to meet the socio-economic development demand. The total length of Hanoi road is about 200 km, road density 5.4-5.6Km/km^2, area for road is only 4.7-5.0 % of total area. The area for static traffic (parking place) is serious shortage.

The development and growth in population and economy has resulted in the increase of number and type of transport means leading to the urgent need of concentrating on solving raised problems accordingly. Firstly, the relation between national roads and urban road has not been clearly determined, ring roads have not been really established that the radial roads are overloaded as a result. Traffic composition is complicated with quite high proportion of non-motorized vehicles as showing in table1.

Table 1. Traffic composition in some main roads of Hanoi 1988

	Road type	Road Name	Bicycle & rickshaw		Motorcycle		Automobile	
			vehicle/ day	%	vehicle/ day	%	vehicle/ day	%
1	Radial roads, Ring roads	Nguyen Trai	105770	36	176885	60	12899	4
		Highway No.32	98216	44	115822	52	6678	3
		Nam Thang Long	18639	34	24972	46	11099	20
		Lang	38510	40	54500	56	3736	4
		Truong Chinh	48703	40	65834	54	6527	5
		Le Duan	53131	26	144229	70	9646	5
2	Arterial	Dai Co Viet	64861	29	150843	67	8581	4
		Tran Quang Khai	15146	12	88018	67	27963	21
		Hoang Quoc Viet	15047	34	25611	59	3085	7
		Lang Ha	35703	25	96052	68	9216	7
		Minh Khai	38821	48	38495	48	2953	4
		Thai Ha	43437	25	118603	70	8472	5
3	Local	Kim Ma	28144	26	69986	64	10642	10
		Dinh Tien Hoang	25422	25	73219	71	4682	5
		De La Thanh	47332	36	81124	62	2429	2
		Duong Buoi	16753	39	25146	58	1602	4
		Bach Mai	57862	44	72945	55	1401	1

The growth rate of vehicle is high but not follow a certain trend distribution.

Table 2. Number of motorized vehicle in Hanoi in recent years

Year	Automobile		Motorcycle		Year	Automobile		Motorcycle	
	unit	%		%			%		%
1985	27543	-	64488	-	1993	53100	9.0	467232	5.19
1989	27345	-0.7	158038	145.1	1994	57036	7.4	512612	9.7
1990	32269	18.0	212303	34.3	1995	64716	13.5	557992	8.9
1991	38567	19.5	270650	27.5	1996	69375	7.2	595730	6.8
1992	48710	26.3	307657	13.7	1997	84436	21.7	626565	5.2
Annual growth rate							***13.5***		***33.7***

Many roads with narrow width, small bending radius, narrow or non walk-side, no pedestrian cross-pass, no traffic signal, are in bad condition. Intersections are often controlled and managed inefficiently due to lack of experience. Public transport almost can not promote its effectiveness. Congestion happens in intersections very often. Traffic accidents are likely increasing.

To improve the Buoi intersection in accordance with development master plan of Hanoi, the neighborhood and reference areas were also covered in the study. The Buoi intersection study case area is about 14ha with the central point is Hoang Quoc Viet and Buoi road.

The existing intersection is shown in figure 2 intersecting 5 non-convergent roads with narrow pavement width (8-10m), no walk sides in most roads and high-density inhabitant. The Buoi market is located at the center of the area, which opens from early morning until late evening. The vehicle densities in roads are quite high, chaotic traffic causing inconvenience and difficulty for road users to percept their direction. Besides, differences of terrain level also make vehicles interchanging direction difficult especially for non-motorized vehicles. In rush days or rush hours, the intersection legs become overloaded. With rapid

growth rate of traffic demand, the serious congestion will occur at this intersection if it is not improved.

1.2. Transport Development Plan for Hanoi and Buoi intersection up to the year 2020

According to the Transport Development Plan up to the year 2020 passed in 1993 and adjusted plan passed in 1998, Hanoi will be the a modern city, a center for political, economy and culture of the whole country. City population will be up to 5 mill. of which 2.5 mil in urban area. Travel demand is reckoned to be 2,040,000,000 trips/ year or 2.63 trips/person/day by the year 2020. The total area of the city is 25,000 ha of which 7,000 ha will belong to transport land-use (20-30%). National roads passing the city include Highway No.1, No.2, No.3, No.5, No.6, No.32, No.18, Lang Trung-Hoa Lac, etc. Urban road network consists of radial roads, ring roads and local roads as follows:

- Ring roads: Ring road 1, Ring road 2, Ring road 3, and Ring road 4 run through areas of Vinh Tuy bridge, Nga Tu So, Cau Giay, Buoi, Dong Anh.
- Radial road through Buoi starts at Phu Dien railway station, intersects Ring road 3, joints Hoang Quoc Viet road then enters Ba Dinh. Furthermore, the direction to Ba Dinh through Buoi will attract traffic from Son Tay on Highway No.32, from Noi Bai International Airport on Nam Thang Long road, from Northern urban area through Dong Anh bridge and form Ring road 3.

Buoi intersection is four-leg intersection of two main roads: Hoang Quoc Viet joining Hoang Hoa Tham road to enter Ba Dinh and Ring road 2 as showing in figure 1.

Thus, Buoi will be one of 38 main intersections of Hanoi according to development plan. Buoi will have very important role when the Northern Urban Area is formed, Dong Anh bridge is built and Ring Road 2 promotes most its effectiveness. Buoi will be the important threshold of the city center. Otherwise, when being completely constructed, Buoi intersection itself will attract traffic from other directions making the traffic in the area be adjusted, reducing traffic for Cau Giay neighbor intersection, for Highway No.32, Nam Thang Long, Lang roads etc. so that the traffic quality of the city will be significant improved.

For its important role in the Transport Development Plan of Hanoi approved by the Primer Minister, Buoi intersection is in urgent need of investment for construction.

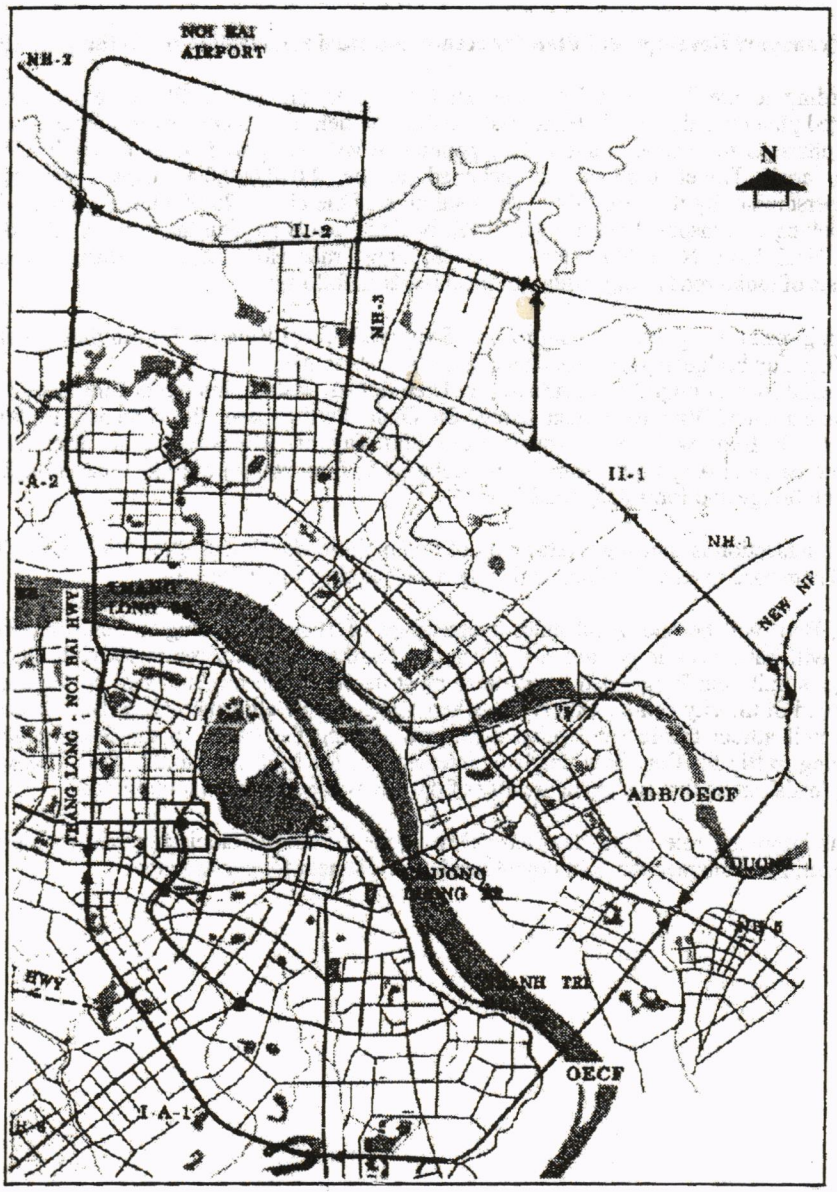

Figure 1. The Transport Development Plan up to the year 2020 of Hanoi city

2. STUDY ON TECHNICAL SOLUTIONS FOR BUOI INTERSECTIONS

2.1. Traffic Survey

In process of Feasibility Study of Buoi intersection, surveys were conducted on topography and geographic conditions, drainage, underground constructions, plan for Buoi dyke, cultural and historical constructions, population density, existing constructions, environmental forecast, traffic survey etc. to get data for calculation and technical proposals. The following only focuses on traffic data collection.

2.1.1. Objectives, Requirements and Activities of Traffic Data Collection.

Traffic data collection was conducted to determine:

- Vehicle flow in a day, in rush hour
- Vehicle composition
- Vehicle growth rate in forecast when Buoi intersection is completed

11 traffic-counting stations were set up on roads in reference area (figure 2).
Counting works were taken for both directions of roads from 5:000 to 23:00. The days were chosen for counting are: an any day in the week (Friday), a weekend day (Saturday), an early day of week (Monday) and a day off (Sunday).

2.1.2. Processing Collected Data

Data collected were processed as follows:

- Adjusting traffic volume/day: based on the collected data of vehicle number from 5:00 to 23:00 [$N_{5\text{-}23}$], determine traffic volume/day [N_{ngd}] by

$$N_{ngd} = N_{5\text{-}23} * 110\ \% \qquad (1)$$

- Converting vehicle: According the Procedure TCVN 4449-89, all kinds of vehicle are converted to car

$$N_{qd} = a * N_{ngd} \qquad (2)$$

Where:
N_{qd} : number passenger car equivalent unit
a: passenger car equivalent coefficient, depends on vehicle type as shown in table 3

- Traffic flow in rush hour [N_{cd}] :

$$N_{cd} = (0.1\text{-}0.2)\ N_{qd} \qquad (3)$$

- Annual vehicle flow growth rate (q)

2010 and 2020 were taken into calculation. Based on the GDP growth rate of Hanoi, data on table 2 and data from approved projects, annual vehicle flow growth rate take 7% (non-motorized:0%)

- Vehicular flow capacity at cross section:

$$Z = m * N_{cd}/n * N \qquad (4)$$

Where:

n : number of traffic lane

N: Saturated flow capacity = 1800 veh./h/lane when the road have separation between Motorized and Non-Motorized vehicle; = 1500 otherwise

m: Coefficient for capacity utilization
m = 0.55 when V ≥ 80Km/h
m = 0.66 when 40<V<80 km/h
m = 0.77 when V≤ 40 Km/h

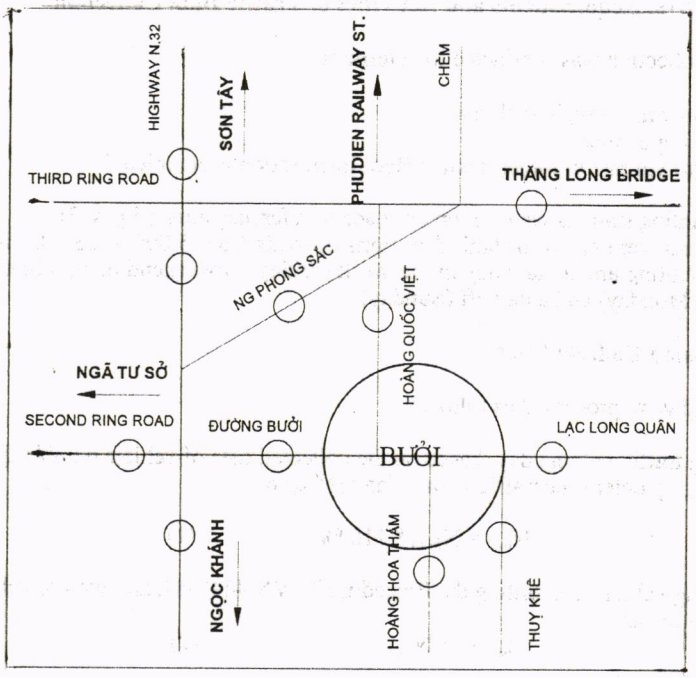

Figure 2. Diagram of traffic-counting stations

Table 3. Passenger Car Equivalent (Standard vehicle equivalent)

Vehicle type	a
Car	1.0
Light truck (2T)	1.5
Heavy truck (5-14 T)	3.5
Bus	2.5
Motorcycle	0.5
Cycle	0.3

2.1.3 Summary of Traffic Flow Calculation Results on Roads in Buoi Sudy Area

Table 4. Vehicle flow passing Buoi intersection

No.	Surveyed roads	Counting station position	Surveyed year 1998	Study year	
				2010	2020
			Out/in	Out/in	Out/in
1	Highway 32	The gate of National University	55102 *58132*	124100 *130924*	244124 *257548*
2	Nam Thang Long Road	Consultant Design company for Water Construction	25376 *21586*	57152 *45616*	112426 *95635*
3	Lang Road	The gate of RITST	27985 *22075*	63028 *49717*	123985 *97801*
4	Hoang Quoc Viet Road	The gate of college for children	12670 *10889*	28535 *24524*	56133 *48243*
5	Lac Long Quan Road	Fuel station No.10	8597 *8125*	19362 *18299*	38088 *35997*
6	Thuy Khue Road	The gate of Buoi People Committee	6558 *11798*	14770 *26571*	29055 *52270*
7	Hoang Hoa Tham Road	The gate of Automobile breaker company	17074 *9160*	38454 *20630*	75645 *40582*
8	Buoi Road	The gate of Hanoi Zoo	8616 *12878*	19405 *29004*	38172 *57055*

2.1.4 Forecasting the Vehicle Flow Passing New Buoi Intersection in the First Year of Operation and Following Years

A model of vehicle flow distribution passing new Buoi intersection the first year of operation and following years was set up by analysis and computation based on the Development Plan and collected data (table 4). The plan of traffic re-distribution in roads, which are categorized, in the area and traffic attraction to this intersection were taken in to consideration during study process. The results are shown in figure 3

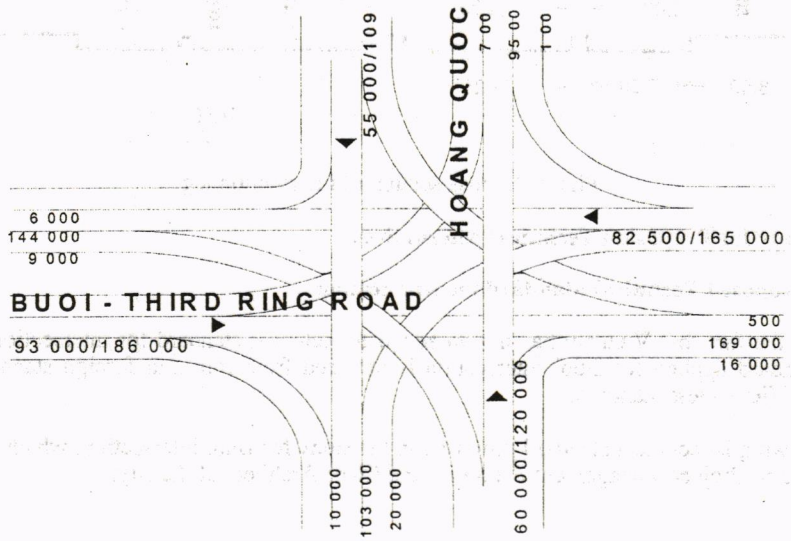

Figure 3: Forecasting vehicle flow passing Buoy Intersection in 2020

2.1.5 Determination of Cross-section Geometry and Minimum Lane Number

Corresponding to vehicle flow rate at rush hour in study year, minimum lane number was determines to enable intersection flow capacity with speed of motorized vehicle of 40Km/h, non-motorized vehicle of 12-15 km/h. In comparison with specifications of development plan, it showed a relative suitable results. Hoang Quoc Viet road and Hoang Hoa Tham road are 1st class roads with cross width of 60 m according to development plan. This study presented a width of 50m with 4 motorized lanes (4*3.75m), 2 non-motorized lanes (2*3.00m), and median between two directions, no separation between motorized and non-motorized vehicle lanes. In future when traffic increases, two motorized vehicle lanes will be added in inner area (central line) (2*3.75m), and separation may be installed between motorized and non-motorized vehicle lanes.

- Ring road 2 has width of 60 m according to development plan, the study-selected 57.5m : 6 motorized vehicle lanes (6*3.75m); 2 non motorized vehicle lanes (2*7.00m); median and separation between motorized and non-motorized vehicle lanes. (refer figure 4)

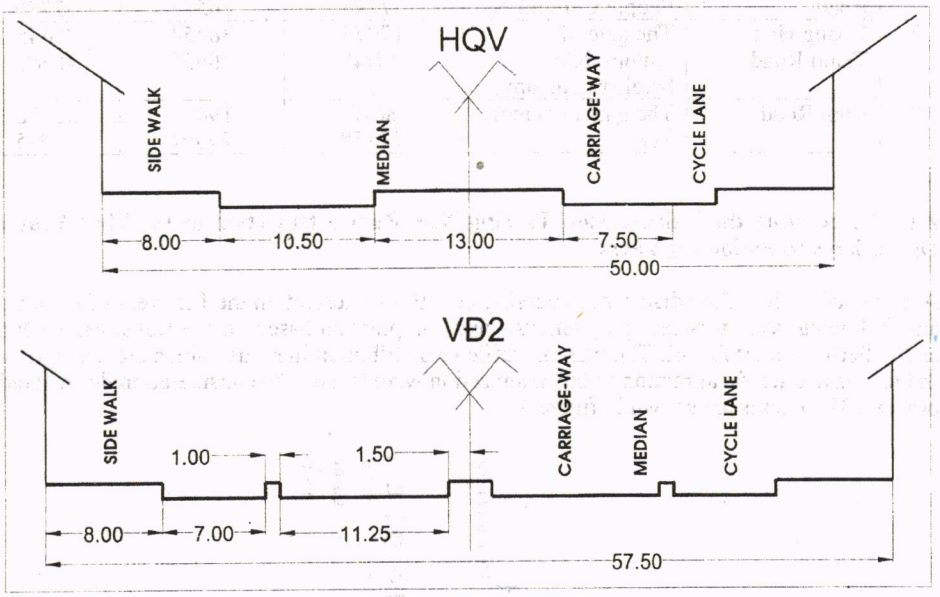

Figure 4: cross-section of intersection leg.

2.2. Study for Proposing Technical Alternatives

2.2.1 Proposed Technical Standard for Application

Due to the fact that Vietnam has not an adequate technical standard for intersection design, the standard applied for Buoi intersection is obtained from referring foreign standards and current Vietnamese standard.

The flowing is technical standard proposed in the study for Buoi intersection, which has been approve by Project Management Authority and Chief Architect of the city.

Table 5. Technical standard applied for Buoi intersection

Parameter	Unit	USSR	USA	Draft of sector standard		VN standard	Approved plan	Application	
				At grade	Grade			Motorized	Non-motorized
V_{tt}	Km/h	≥60	24-40	40	40	-		40	12-15
R_{tr}	m	60	15-46	-	30	30	>25,<40	40	15
R_{ph}	m	150	-	-	50-60	100	<25,<40	40	15
$i_{longitudinal}$	%	4	4	5	6	5		5	2
$i_{superelevation}$	%	≤6	6	6	6	≤6		≤6.0	-
$i_{vertical}$	%	-	-	2	2	2		2	2
$L_{sight-distance}$	m	-	-	≥30	-	-		≥30	-
$H_{clearnace}$	m	-	4.2	-	4.5	4.5		4.5	2.5
$L_{mixed\ stream}$	m	(2-4)V_{tt}	40	-	-	-		40	-
Entry cross section	m	- H Q V Road - V D 2 Road					50 60	50.0 57.5	

2.2.2 Study on Geometric Structure for Buoi Intersection

The study focused on two main parameters: The theoretical flow capacity represented by average speed (V_{nut}) of the intersection and accidental parameter represented by the minimum conflict numbers (G) in the intersection provided that the intersection can ensure the design vehicle flow (Q_t)

2.2.2.1 Some Main Assumptions.

Analysis and calculation were carried out based on following assumptions:

- Speed of motorization vehicles (V_{cogioi}) through the intersection is 40Km/h, non-motorization vehicles (V_{thoso}) is 12 Km/h;
- Number of motorized lanes in Hoang Quoc Viet road: 2 * 2 = 4
- Number of non-motorized lanes in Hoang Quoc Viet road: 2 * 3 = 6
- Number of motorized lanes in Ring road: 2 * 3 = 6
- Number of non-motorized lanes in Ring road: 2 * 6 = 12
- Automobile lane width: 3.75m; motorcycle: 1.25m; cycle: 1.00-1.10 m
- The calculation was taken at rush hour when the traffic flow passing a cross-section is maximum.
- Considering that the influences of vehicles passing intersection are equal

2.2.2.2. Case 1: At-grade Intersection Using Roundabout.

Taking the average width ($B_{avegare}$) of two directions are 50m, speed of motorized vehicle is 12km/h and equals to speed of non-motorized vehicle, right-turning radius (R_{right}) is 40m, then minimum diameter of the roundabout can be obtained as follow (refer figure 5):

$$Dx = 4 * (L_1 + 2*L_2 + L_3)/\pi \qquad (5)$$

Where:

- L_1 : Average distance between two opposite directions = 24.00m

- L_2 : Distance on roundabout curve between central line of one direction and point which right-turn vehicle stream meets the roundabout curve. L_2 depends on the right-turning radius and $V_{tt.}$. From table 4: $V_{tt.}$ = 40km/h; R_{righ}= 40m obtains $L_2 \approx 24.20$ m

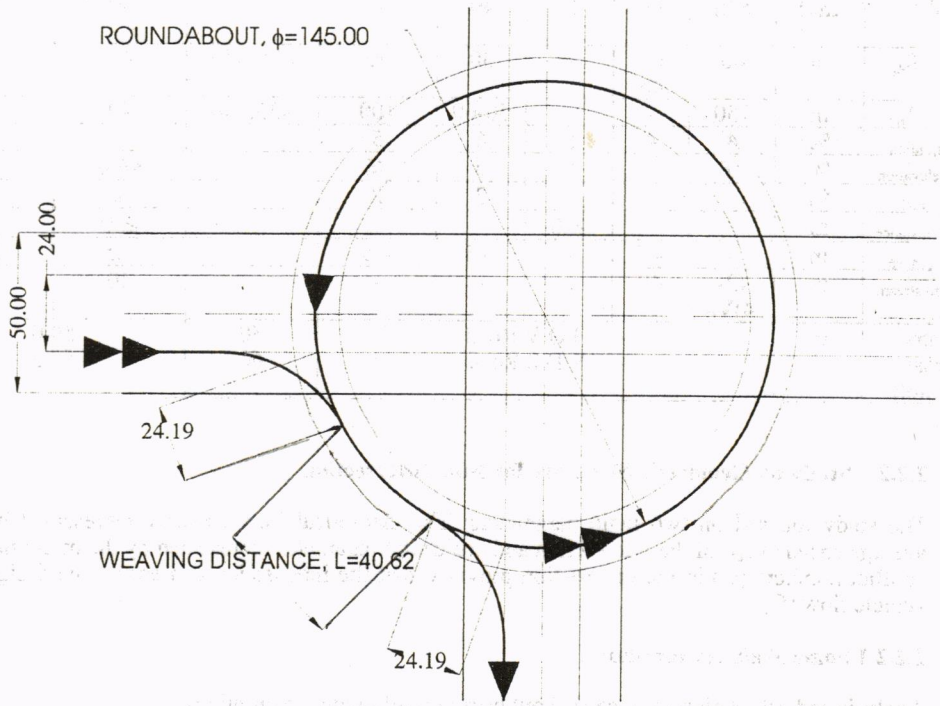

Figure 5: At-grade intersection using roundabout

- L_3 : Mixed stream length $L_3 = f*Vx$ if $f = 3 \div 4$, $Vx = V_{non\text{-}motor.} = 12$km/h then $L_3 = 40$m

Substitute in (5)

$Dx = 4 * (24.00 + 2 * 24.20 + 40.00)/\pi \approx 145$ m

Therefore, in roundabout alternative, because of mixed stream of non-motorized and motorized vehicle, the speed of motorized vehicles is equal to non-motorized. In other word, the average speed of mixed vehicle stream through the intersection (V_{nut}) is equal to the speed of slowest vehicle. That means, in this specific case the average speed in the roundabout with diameter at minimum of 145m is 12Km/h at maximum. If the weaving entry width (the cross-section width of pavement in roundabout) is extended then the average speed will be improved. However, the diameter of the roundabout will be larger resulting in the increase of the land-use.

2.2.2.3. Case 2 - At grade Intersection Using 6 Phases - Traffic Light.

In the case of at grade intersection controlled by 6-phase traffic light, it is shown that there won't be conflict happening if left turning is arranged on converse direction (see figure 6).

Due to 6 phases controlled, the time passing intersection of vehicle increases more than 6 times, thus, the average speed passing intersection ($V_{intersection}$) will be reduced by 6 times too.

In concrete, $V_{motor} < 40/6$ km/h; $V_{non\text{-}motor} < 12/6$ km/h. Therefore, flow capacity reduces more than 6 times. However, in this case, in principle, V_{mortor} and number of non-motorized traffic lane can be increased (because $V_{non\text{-}motor}$ can't be increased). But it leads to the fact that land-use will be increased.

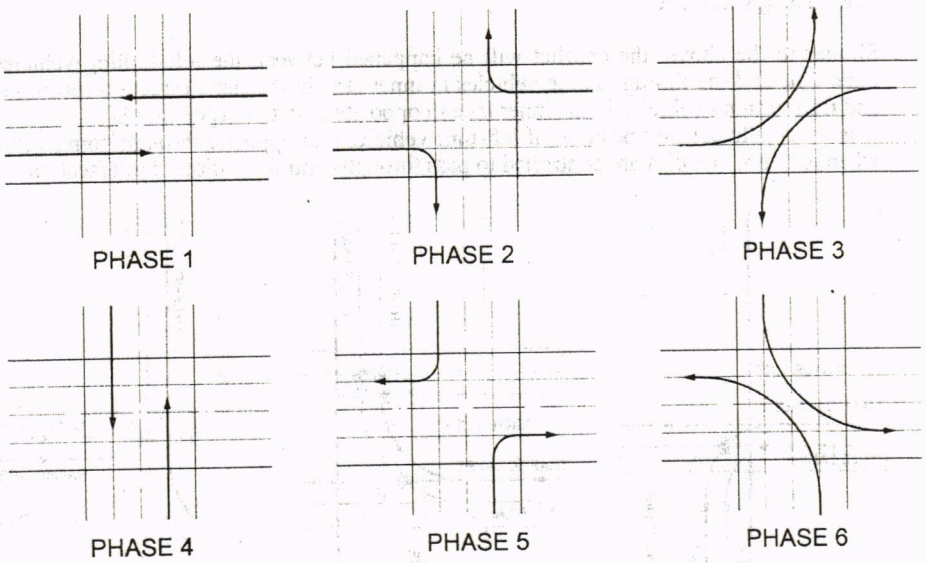

Figure 6 - At grade intersection controlled by 6-phase traffic light.

2.2.3.4. Alternative 3: At-grade Intersection Controlled 2-phase Traffic Light.

In the case of at grade intersection using 2-phase traffic light, if there is only one traffic lane in each direction, in principle, there will be one conflict happening with left turning vehicle. See figure 7.

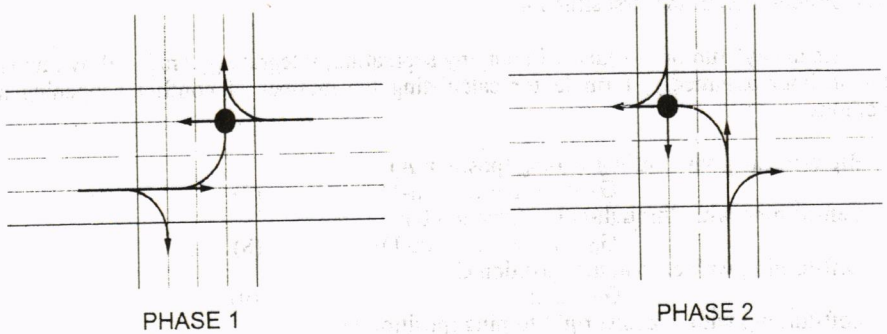

Figure 7: At grade intersection using 2 phase traffic light

If the number of traffic lane increases (n>1), conflicts occur more immediately. Followings are positions and number of conflicts happening in the considered situations. (Figure 8)

- Right-turning vehicles, if being well managed in term of geometry, from inner traffic lane must be separated in order to join with the most outer lane. In case there is a absence of a section for vehicle separating and integrating or the inner motorized traffic lane is separated with the outer non-motorized lane by raised separator, then, right-turning motorized vehicle in the inner lane will conflict with the through-going vehicle in the outer lane (position A).

- Similar to the above, the conflict will be happened between the left turning vehicles in outer lane and the through going vehicles in inner lane in the same direction (position B), and right turning vehicles in the inner lane in opposite direction. (position D).
- C is inevitable conflict position of left-turn vehicles and opposite through going vehicles when left-turn vehicles are controlled to pass through central position of intersection.

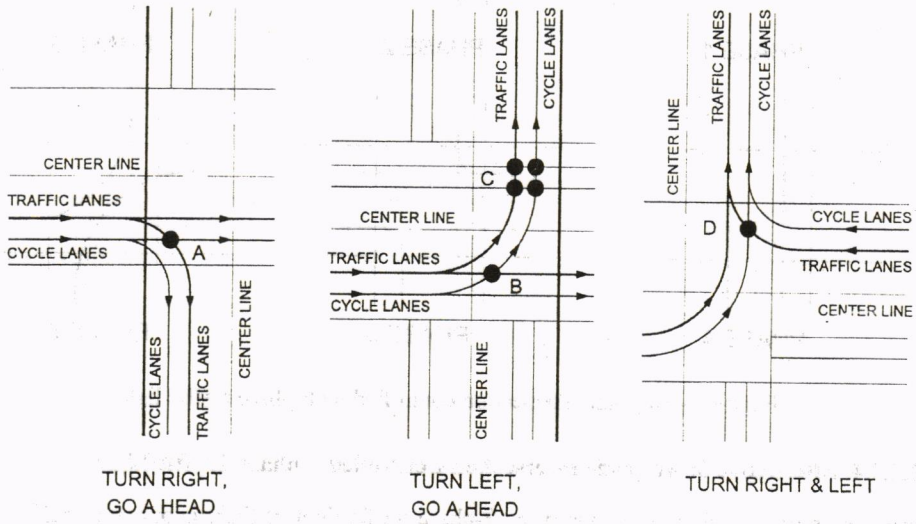

Figure 8. Conflict positions in the case of using 2- phase traffic light

3a) Consideration of the first situation:

Vehicles always run on it's lane without any separating, integrating. Traffic flow rate is max at rush hour assumedly, formula for calculating the number of conflict happening at the positions:

- Right-turning with through-going (position A):
$$G_A = 1 + 2 + \ldots + (n-1) \quad (7)$$
- Left-turning with through-going (position B):
$$G_B = 1 + 2 + \ldots + (n-1) \quad (8)$$
- Left-turning with on-coming (position C)
$$G_C = n\text{^}2 \quad (9)$$
- Left-turning with opposite right-turning (position D)
$$G_D = 1 + 2 + \ldots + (n-1) \quad (10)$$

And sum of conflicts happening at the positions by one phase will be

$$G_T = G_A + G_B + G_C + G_D = 3 * G_A + G_D \quad (11)$$

Where:
n: number of traffic lane in one direction, n = n1 + n2;
n1: number of motorized lane
n2: number of non-motorized lane

Applied in Buoi intersection, the number of conflict at different positions and number of the conflict by phases are listed statistically in table 6 below:

Table 6. Conflict at positions and different phases

Phase	Mixed flow	n1	n2	$G_A=G_B=G_C$	G_D	G_T
Phase 1	Automobile and non-motorized	2	3	10	25	55
	Motorcycle and non-motorized	6	3	45	81	126
Phase 2	Automobile and non-motorized	3	6	45	81	126
	Motorcycle and non-motorized	9	6	120	2225	345

3b) Consideration of the second-situation:

Traffic flow, which is about to pass the intersection, is max. at rush hour and there is an arrangement of a mixing stream section for each component of the stream separately.

In condition of separating and integrating vehicle stream, right-turning (left-turning) vehicles have to ask for priority, to separate from the stream and joint to the most outer lane (inner lane) before turning right (or left). With such above condition, in principle, the number of conflict would decrease to the two lanes in each direction (7 conflicts). But vehicle movement capacity of the intersection would be reduced from 5 to 15 times accordingly to $V_{motorized}$ + 40km/h; $V_{non\text{-}motorized}$ = 12km/h and the vehicle stream started to be chaotic.

3c) Consideration of the third alternative:

Traffic flow, which is about to pass the intersection, is max. at the rush hour and a mixing section for all components of vehicle stream is arranged.

In such condition in principle, there will be only one conflict position at C. But due to the mixing of the motorized and non-motorized vehicle, so, besides the complex and chaotic of the traffic flow, the through-going capacity will be reduced from 14 to 24 times with $V_{mototized}$ $=V_{non\text{-}motorized}$ = 12km/h. In the other word, average speed of vehicles passing intersection ($V_{intersection}$) towards 0 km/h.

Briefly, from the above analysis and calculation, it can be said that the participant of the non-motorized vehicle flow in the intersection break down the vehicular flow theory. Furthermore, based on the data collected from observation and survey at the intersections in Hanoi in combination with the characteristics on topography and dyke etc. of Buoi intersection, an idea of separating non-motorized vehicle flow was proposed.

3. INTRODUCTION OF BUOI INTERSECTION ALTERNATIVES

3.1. Main Principles.

As mentioned before, all proposed alternatives would focus on solving the problem of mixed vehicle flow passing the intersection. The alternative has to ensure the principle that the motorized vehicle flow does not mix or conflict with non-motorized vehicle flow. Hence, the solution for all alternatives is separation of motorized vehicle flow. Specification standard for non-motorized vehicle flow is: maximum longitudinal slope of 2%, minimum radius of 15m, speed of 12-15km/h. Motorized vehicle flows intersect at separate grade with maximum longitudinal slope < 5%, minimum radius of 40m, speed of 40km/h. Motorized vehicle flow is given priority while enabling the convenience for non-motorized vehicles. It should make full-used of vacant available land and the area of low inhabitant density, easy for phased investment, nice landscape and modern. The intersection should be simple in construction and convenience in operation, mitigate the environmental pollution.

The priorities for directions are as follow in sequence:

3. Through-going direction
4. Right-turning direction from Ba Dinh to Nhat Tan on Ring Road 2; left-turning direction Nhat Tan to Ba Dinh on Ring Road 2.
5. Right-turning direction from Cau Giay to Ba Dinh on Ring Road 2; left-turning direction from Ba Dinh to Cau Giay on Ring Road 2.
6. From Lac Long Quan Road to go in and out the intersection
7. Other directions.

3.2. Drafted Alternatives

There have been 6 drafted alternatives:

1. Interchange (or grade intersection) with two complete grades, fly-over over dyke
2. Interchange with two incomplete grades, fly-over over dyke
3. Interchange with two grades, fly-over in combination with digging dyke

4A. Interchange with two incomplete grades, digging dyke in combination with fly-over.

4B. Interchange with two and a half-incomplete grades, leveling dyke, separating non-motorized vehicle flow by tunnel thought dyke and viaduct.

5. Interchange with three grades, two fly-over over dyke and over each other.

Alternative 4 was chosen for presentation in feasibility study report.

3.3. Selected Alternative 4B

- The central point of the intersection is the intersected point between central line of Hoang Quoc Viet road and Buoi Dyke road.
- Central direction is the direction of Hoang Quoc Viet straight to Hoang Hoa Tham at position of Hoang Hoa Tham school. The high level of central point is 3m creating beneath clearance for non-motorized vehicle flow from North to South a versa.
- Vehicle flow passing the intersection to Ring road 2 by an fly-over, which consists of 2 bridges fixed with each other at central line of the road with length of 333.83m, width of 26m (6 motorized lanes). Non-motorized vehicles are separated from fly-over and go on the ground road with the width of 7m.
- Vehicles make left-turning from Ring Road 2 to 2 directions by two bending fly-overs with length L_1 = 199, L_2 = 155m, Width B = 10m (2 motorized lanes). Non-motorized vehicles are separated at the foot of the fly-overs and joint the vehicle flow of two quadrate directions in ground road.
- Vehicles make right-turning from Ring Road 2 to 2 directions by ground road consists of 1 motorized lane and 1 or 2 non-motorized lanes
- Vehicles make left-turning from Ba Dinh by a road consists of 1 motorized lane and 1 non-motorized lane, pass a roundabout outside the dyke and join Ring Road 2.
- Vehicles make right-turning from Ba Dinh on existing Hoang Hoa Tham, which would be improved with 2 motorized lanes, and join the Ring Road 2.

- Vehicles make left-turning from Hoang Quoc Viet road to Ring Road 2 that going on Hoang Quoc Viet road to a point of 400 far away of central point, then turn left joining right-turn vehicles from Ba Dinh. Non-motorized vehicles go on the ground road and make turn right at the central point of the intersection.
- Vehicles make right-turning from Hoang Quoc Viet road to Ring Road 2 by a road running along To Lich river with 1 motorized lane and 1 non-motorized, then join Ring Road 2.
- A viaduct over Hoang Quoc Viet road serves non-motorized vehicles with the width of 7m, length of 50m and clearance of 2.5m. And a non-motorized vehicle bridge across To Lich river is located 50 south of Hoang Quoc Viet road.
- Thought Buoi dyke, there are two tunnels in the north and south for non-motorized vehicle.

Summary of main specifications for the selected alternative is shown in table 7.

Table 7. Some main economic-technical criteria of the selected option

No	Main economic-technical criteria	Selected option
1	Occupied area, m^2	49,594
2	Number of motorized lane through going without conflict	
	To center direction	4
	To ring road direction	6
3	Number of motorized lane of through going conflict with non-motorized vehicle	
	To center direction	0
	To ring road direction	0
4	min. radius, m	
	main road	400
	turning road	40
	non-motorized vehicle	15
5	Max. longrtudual slope, %	
	Motorized vehicle (go up/down the slope)	4.90/4.54
	Non-motorized vehicle (special section 40m long)	2.0 (2.5)
6	Length of the fly-over, m	333.83
7	Main span, m	26
8	Drain age capacity	Good
9	Convenience for non-motorized vehicle	Very convenient
10	Traffic safety degree	No intersection
11	Highest point of the construction, m	16.53
12	Affect level to Buoi dike	Less affected
13	Sum of investment	361/25.8
	Settlement, billion VND/mill. USD	165/11.8
	Infrastructure, billion VND/mill. USD	145/10.4
	Other expenditures, billion VND/mill. USD	51/3.6

4. CONCLUSION:

From the general studies on traffic condition of Hanoi city and special characters of each area, based on survey results, analyzing and necessary calculation, an grade intersection (or interchange intersection) with two and a half grades has been selected to apply for Buoi intersection. This will lead to increasing the through-going capacity, decreasing conflict and reducing traffic accident and cost for resettlement as well.

- Making clear the criteria that need to be compared during designing intersection with mixed traffic flow.

- Recommending idea to separate the non-motorized vehicle stream from the motorized vehicle stream when through going intersection.

- When designing at-grade intersection using roundabout, it is necessary to calculate the radius of the roundabout based on the presence of mixing vehicle streams, avoiding small radiuses as at present causing traffic congestion.

- At the intersections using traffic lights, the number of phase may be increased, especially in large intersections with high vehicle flow rate.

- At the intersections, which are not big and can be improved for increasing through-going capacity, it is needed to arrange a lane for right -turning before traffic light.

- It is needed to work out a plant for separating non-motorized vehicle stream from motorized stream when building new road, even for existing streets if possible.

- It is compulsory to arrange sections for separating and integrating traffic flow at the turning and U-turning positions.

- It is possible to use the calculated results of this project as reference for designing at grade and grade intersections.

- However, this is only primary research result to meet the urgent demand. It needs further more studies.