USE OF ANALYTIC HIERARCHY PROCESS (AHP) FOR SOLVING TRAFFIC ISSUES DUE TO AD-HOC URBAN PLANNING

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Abstract

In Sri Lanka traffic issues are becoming progressively worse due to ad-hoc urban planning. Delays, environmental pollution, higher depletion of petroleum, and increase in stress level of road users are some direct impacts from traffic congestion.

To identify the causes for traffic congestion and to seek for possible solutions, Galaha Junction to Gatabe Roundabout in Kandy – Colombo road (AA 001) was selected as the case study area. The data was collected using series of traffic surveys (vehicle volume counts, pedestrian counts, delay survey, etc) and analyzed to exemplify the gravity of the traffic congestion due to ad–hoc road side developments. The shockwave analyze was performed to find the delay time and queue lengths. It is found that, the existing capacity of the road is not enough to carry the current traffic load, and pedestrian must separate from the vehicle according to the AUSTROADS classification. To minimize the problem, alternative traffic solutions are proposed for both vehicle flows (e.g., flyover, road widening and tunnel) and pedestrian flows (e.g., overpass and underpass). Next a set of criteria are defined to evaluate the best solution. Cost of each solution, environmental impact from the solution, land acquisition requirement for each solution, construction time and the demand (time taken to get down the Level of Service (LOS C to LOS D)) were selected as the criteria. Environmental impact is taken as a qualitative criterion while others are taken as the quantitative criteria. Analytic Hierarchy Process (AHP), a commonly used multi criteria decision support system, is used to obtained best alternatives for smooth vehicular flow and safe pedestrian crossing separately. Later tree diagram concept was used to reach the best composite solution for the problem. The fly over for vehicles and the underpass for pedestrians are the best solution from AHP.

Keywords: *Traffic issues, Ad-hoc urban planning, Analytic Hierarchy Process (AHP)*

Introduction

Road traffic congestion has become a serious issue in urban areas in developing countries due to several reasons; carelessness of drivers, lack of traffic controlling systems, poor road signs, increasing number of vehicles and ad-hoc land use planning. This paper addresses the traffic issues generated by aforesaid factors in urban arterial roads how the developed feasible solutions are obtained. However, the most appropriate solution depends on many constrains; capital investment, environmental concerns, land acquisition, social issues are few to mention with. To address the problems in this nature, multi-criteria decision support systems can be used. The aim of the paper is to exemplify such a case study in Sri Lanka, and bring forward feasible structural measures to overcome the situation. Another objective in this problem is to present the usefulness of AHP a multi criteria decision making system to attain the best feasible solution among many options.

Case Study Area

Kandy is considered as the second main city in Sri Lanka and also it is considered to be one of the most enchanting cultural heritages. Between Galaha junction and Gatambe roundabout in Colombo Kandy road (A 001), there are number of important places, such as Peradeniya Botanical Garden, Peradeniya University, Peradeniya General Hospital, Peradeniya Dental Hospital, Peradeniya Veterinary Hospital, Gatabe Bodhiya, Sarasviuyana School, Peradeniya Police Station, to which a large number of people visit each day (Figure 1). The increased number of vehicles as well as the increase number of pedestrians aggravates the massive traffic congestion in the road section considered.

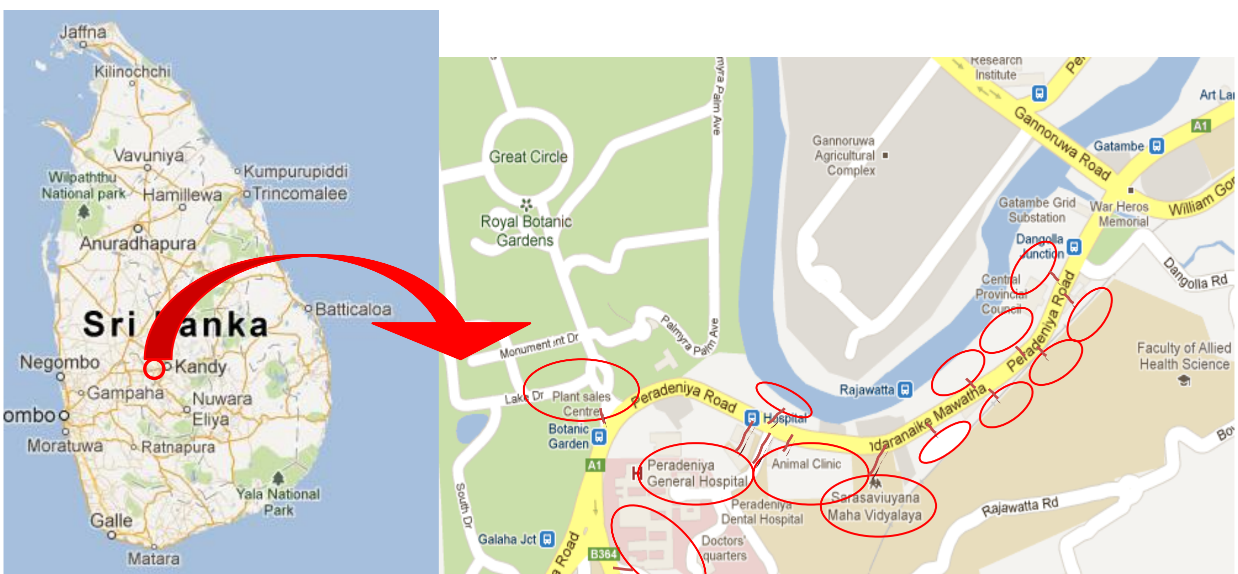

Figure 1: Case study Area

Methodology

To justify the traffic issues resulted from ad-hoc urban planning, traffic surveys (e.g., vehicle count, delay surveys, speed surveys, pedestrian surveys) are conducted. By analyzing the collected data, the problem is quantified. Next to find the possible alternative structural changes, road side land use characteristics, geological factors and attitudes of the people are studied. Then alternatives are proposed based on cost/benefits, environment effects, construction time frames etc. Finally, Analytic Hierarchy Process (AHP), a multi-criteria decision making tool introduced by Saathy, 1980 is exemplified to be used alternative selection in traffic matters like above.

Data collection

(1) *Traffic volume survey data*

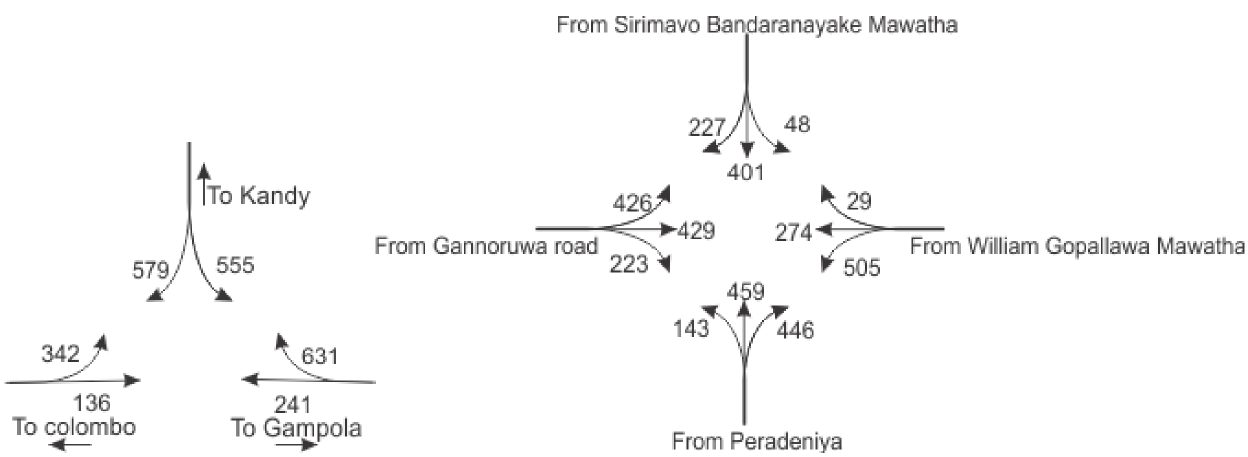

Figure 2 (a): At peradeniya junction *Figure 2 (b): At Gatabe Roundabout*

Figure 2: Location and the traffic volume data

(2) *Pedestrian count Survey Details*

At the pedestrian crossing near the Peradeniya General Hospital

Table 1: Pedestrian survey summary

Peak Hour	Number of Pedestrians cross the road (both directions)
06:15-07:15	1057
11:15-12.15	1233
17:30-18:30	1086

Turning movement survey at the Peradeniya General Hospital Junction, from the entire vehicle coming from the hospital and coming to the hospital are calculated. (Their shown in major conflict only)

Percentage conflict of right turners from the hospital : 56.94%

Percentage conflict of right turners to the hospital : 33.33%

Data Analysis

According to the data which have observed are clearly shows the amount of traffic congestion in studying area. To clarify it can be done further analysis as follows.

(a) Road Capacity Calculation

To see whether current road capacity is enough or not,

From the surveyed details

Vehicles in peak hour = 2107

Take the peak hour factor as 0.9 and then

Service flow (existing road) = 2342veh/hr

Calculate number of lanes required to be at LOS C case;

MSFc (Service flow of LOS C case road) = 1300

Fhv = 0.63

After the calculation it shows three lanes are needed to have LOS C type condition, among the selected road section but the existing road has only two lanes. Therefore to avoid the traffic congestion there has to be at least 3 lanes.

(b) Pedestrian-Vehicle Conflict Analysis

Then assess the contribution by the pedestrian to the traffic congestion (at the Peradeniya General Hospital road crossing),

From the survey get results as follows,

Peak hour: 11.15 am: 12.15 pm

Peak hour volume: 1233 ped/hr

Flow rate of pedestrians in meter per length: 1.7m^2/ped

Peak volume of vehicle (Kandy to Peradeniya): 1134 Veh/hr

Density of our area =28pc/km/ln

For the analysis purpose assume

Vehicle stops 1 min to cross the road

Average Vehicle length: 6 m

Average Vehicle speed: 40 km/hr

Then using $q = kv$ analyzed the problem.

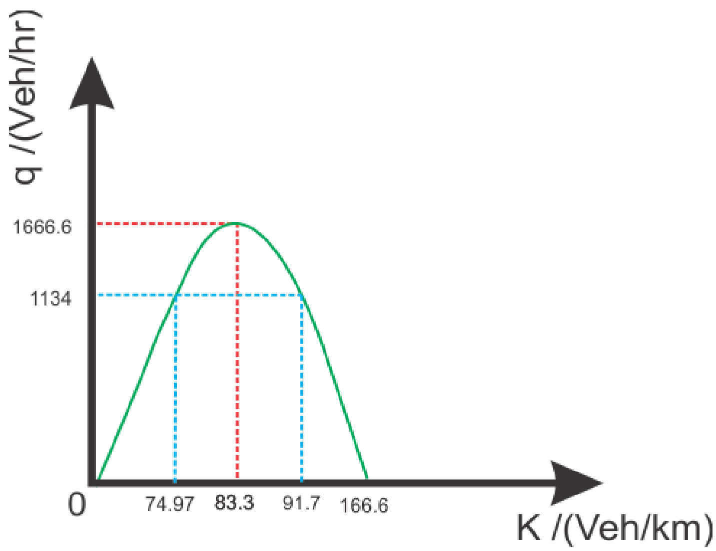

Figure 3: q, k diagram

From the above (Figure 3) diagram results then plot shockwave diagram (Figure 4)

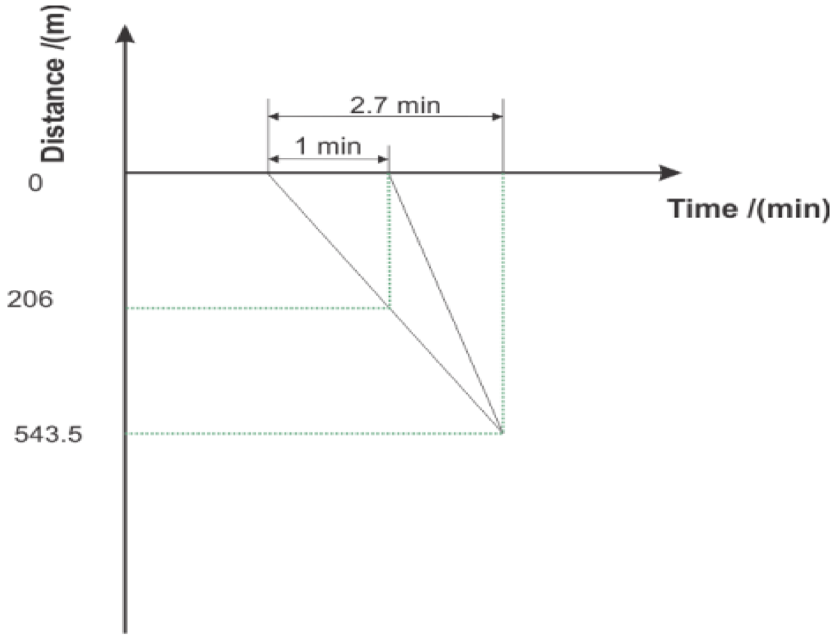

Figure 4: shockwave diagram

Finally found the delay is nearly 3 min and the fleet of the vehicles is 543 m long. This is fairly high traffic congestion.

Then check the pedestrian vehicle conflict (at the peak hour)

$$vehicle \times pedestrian = 1134 \times 1233 = 1{,}398{,}222$$

According to the AUSTROAD classification, if pedestrian flow rate is greater than 250 (1233 ped/hr), vehicle flow rate is greater than 850 (1134 veh/hr) for one direction (if it is consider 2 direction veh/hr is greater than 1500) and the PV conflict is greater than 180,000, there should be separation of pedestrian and vehicle of the road.

From both analyses, it is finally justified that the existing road capacity is not sufficient for the smooth flow of vehicles and for the safety of pedestrian.

(c) Proposed alternative structural road side modifications

The following alternative structural modifications to the road stretch are considered.

1. Widening of the existing road stretch
2. Tunnel beneath the existing road stretch
3. Flyover above the existing road stretch
4. Underpass beneath the existing pedestrian crossing near the Peradeniya Hospital

5. Overpass above the existing pedestrian crossing near the Peradeniya Hospital

Alternatives 1-3 are for vehicular flow while alternatives 4 and 5 are for pedestrian flow. However, the selection of the most effective and feasible alternative or combined alternatives are depends on constraints. (1) Cost, (2) Demand, (3) Construction Time, (4) Land Acquisition, and (5) Environmental Impact were selected to study this problem. Out of those, 'environmental impact' is a qualitative alternative while others are quantitative alternatives. To analysis this problem, two AHP structures were prepared as shown in Figure 5

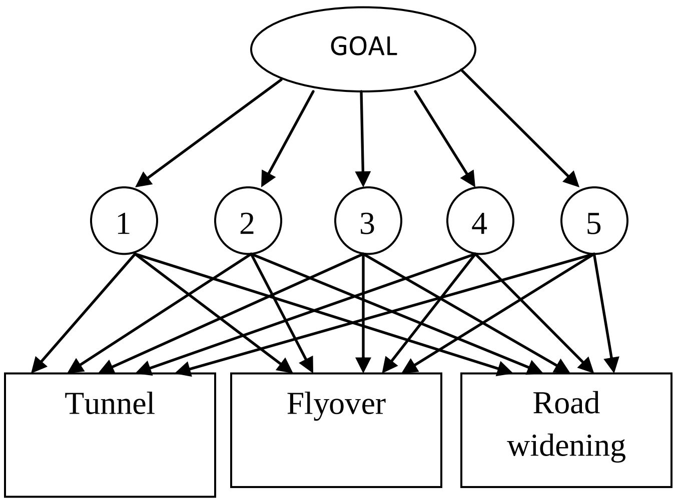

Figure 5 (a): Alternative selection for vehicular flow

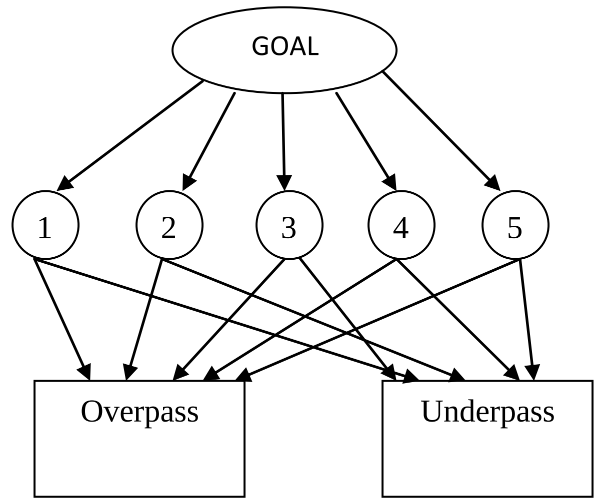

Figure 5 (b): Alternative selection for pedestrian flow

Figure 5: Alternative selection process

AHP Alternative Comparisons

The analysis is divided into two sections;

1) Alternatives for vehicular flow

2) Alternatives for pedestrian flow

The approach is to find the priority vectors for each alternative in two sections; and combined them to attain the best combined alternative solution using a tree diagram concept.

(1) Alternatives for vehicular flow

Alternatives for vehicular flow (Road Widening, Tunnel, and Flyover) are compared with quantitative criteria (cost, demand, construction time, and land acquisition).

Table 2: Quantitative values for alternatives

Alternative	Cost /(million)	Demand /(years)	Construction time / (month)	Land acquisition/(million)
Tunnel	125	10	30	6
Road widening	60	5	10	48
Fly over	100	10	24	12

The alternatives were compared pair wise with qualitative criterion ‘Environmental Impact’.

Table 3: Pair wise comparison for EI

EI	Tunnel	Road Widening	Flyover	Priority vector
Tunnel	1	2	3	0.539
Road Widening	1/2	1	2	0.297
Flyover	1/3	1/2	1	0.164

Then the synthesized matrix was developed as shown in Table 4.

Table 4: Synthesized matrix for three alternatives

Alternative	Cost	Demand	Construction time	Land acquisition	EI
Tunnel	0.439	0.250	0.469	0.091	0.539
Road widening	0.211	0.500	0.156	0.727	0.297
Flyover	0.351	0.250	0.375	0.182	0.164

(2) Alternatives for pedestrian flow

Alternatives for pedestrian flow (Underpass, Overpass) are compared with quantitative criteria (cost, demand, construction time, and land acquisition).

Table 5: Quantitative values for pedestrian flow alternatives

Alternative	Cost /(million)	Demand /(years)	Construction	Land

			time / (month)	acquisition/(million)
Underpass	2.5	10	3	1.1
Overpass	2.4	7	1	1.1

Table 6: Pair wise comparison for EI

EI	Tunnel	Road Widening	Priority vector
Underpass	1	2	0.667
Overpass	1/2	1	0.333

Table 7: Synthesized matrix for two alternatives

Alternative	Cost	Demand	Construction time	Land acquisition	EI
Underpass	0.510	0.412	0.750	0.500	0.667
Overpass	0.490	0.588	0.250	0.500	0.333

(3) Criteria comparison with the goal

Table 8: Pair wise comparison for the five criteria and Priority vector for vehicle flow

	Cost	Demand	Construction time	Land acquisition	EI	Priority Vector
Cost	1	3	3	2	5	0.405
Demand	1/3	1	2	2	4	0.235
Construction time	1/3	1/2	1	1/2	2	0.115
Land acquisition	1/2	1/2	2	1	3	0.182
EI	1/5	1/4	1/2	1/3	1	0.063

Table 9: Priority matrix for three alternatives for vehicular flow

	Cost **(0.405)**	Demand **(0.235)**	Construction time **(0.115)**	Land acquisition **(0.182)**	EI **(0.063)**	Priority Vector
Tunnel	0.439	0.250	0.469	0.091	0.539	0.341
Road Widening	0.211	0.500	0.156	0.727	0.297	0.372
Flyover	0.351	0.250	0.375	0.182	0.164	0.287

Table 10: Pair wise comparison for the five criteria and Priority vector for pedestrian flows

	Cost	Demand	Construction time	Land acquisition	EI	Priority Vector
Cost	1	3	2	3	4	0.385
Demand	1/3	1	3	3	3	0.261
Construction time	1/2	1/3	1	3	3	0.188
Land acquisition	1/3	1/3	1/3	1	2	0.101
EI	1/4	1/3	1/3	1/2	1	0.069

Table 11: Priority matrix for two alternatives for pedestrian flow

	Cost **(0.382)**	Demand **(0.261)**	Construction time **(0.188)**	Land acquisition **(0.101)**	EI **(0.069)**	Priority Vector
Underpass	0.510	0.412	0.750	0.500	0.667	0.540
Overpass	0.490	0.588	0.250	0.500	0.333	0.460

Combined Alternatives

Using tree diagram alternatives for vehicle flow and alternatives for safe pedestrian crossing were studied. Figure 6 shows the complete tree diagram.

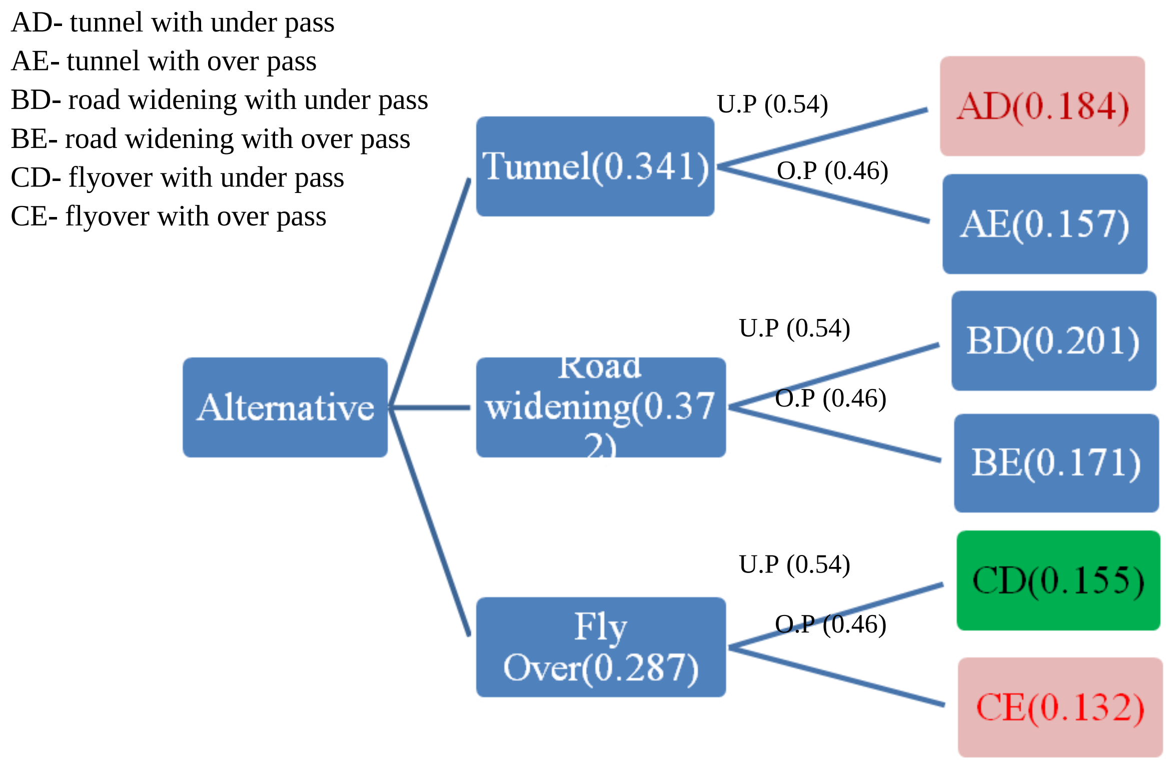

Figure 6: Tree diagram of alternative selection

In this combinations tunnel with underpass and flyover with overpass were impossible because practically cannot do such construction together. According to the above calculations; the combination CD (flyover with under pass) was selected. Although the flyover prepared for the vehicle flow for the short trip vehicle can use the existing road (*see Figure 7*).

Table 12: Advantages and disadvantage of the flyover

Advantage	Disadvantage
No need to much land acquisition	Traffic flow will conflict during the construction
No destruction to existing buildings and other things.	Proper drainage system has to be supplied
Parking capacity can be increased	-
Travel time will be reduced	-
Can promote the view.	-

Table 8: Advantage and disadvantages of the underpass

Advantage	Disadvantage

Pregnant ladies and disable people can use easily	Initially large amount of cost is needed
Journey speed of the vehicles can be increased	Traffic flow will conflict during the construction
Time wasting for crossing is reduce	Proper drainage system has to be supplied
No pedestrian interference for the traffic flow	Lighting and Ventilation should be considered

Conclusion

Fly over, Road widening and Tunnel are proposed to minimize the traffic issues from the vehicles. Overpass and Underpass are proposed to minimize the traffic issues caused by the pedestrians, which also brings the safety for the pedestrian. Having concerned the cost, demand, construction time, land acquisition, the environmental impact, the best possible solution from the above proposed alternatives is chosen using AHP method. From the AHP method Flyover with the underpass was selected as the best option to reduce traffic congestion in the studied area as it brings the highest benefits from the lowest possible cost among the other alternatives.

To overcome such a case by introducing possible hard measures and using the multi criteria decision making system could get the effective and the best solution.

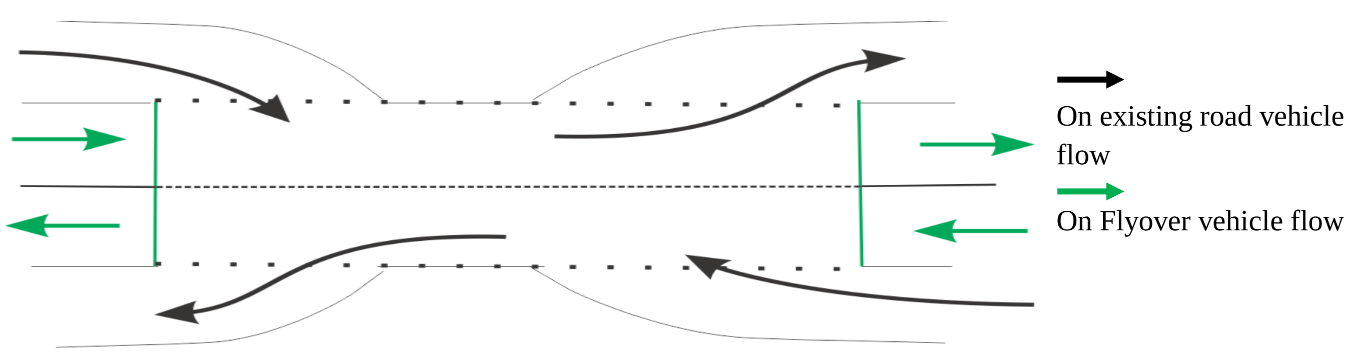

Figure 7: Plan view of flyover and vehicle flow direction

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