African Journal of Basic & Applied Sciences 8 (5): 299-301, 2016
ISSN 2079-2034

DOI: 10.5829/idosi.ajbas.2016.299.301

Discussion of Traffic Flow for a Network of Four One-Way Streets in Adama, Ethiopia via System of Linear Equations

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Abstract: In order to keep traffic flowing, a system of linear equations to determine the number of vehicles that should be allowed to route a four one-way streets in Adama is applied. The systems of equations used in the model were solved analytically using the method of Gauss-Jordan elimination. The work shows that if 181 vph, 127 vph and 216 vph are allowed to route intersection D and C, A and D and B and A of the model respectively, traffic congestion in the area of Adama discussed in the model would be minimized.

Key words: Mathematical model · Traffic congestion · Four one-way · Traffic flow

INTRODUCTION

In mathematics and civil engineering, traffic flow is the study of interactions between vehicles, drivers and infrastructure (including highways, signage and traffic control devices), with the aim of understanding and developing an optimal road network with efficient movement of traffic and minimal traffic congestion problems [1]. Traffic congestion has a number of negative effects on humanity. These include wasting time of motorists and passengers which therefore reduce regional economic health; delays, which may result in late arrival for employment, meetings and education, resulting in loss of businesses, disciplinary action or other personal losses. Blocked traffic may interfere with the passage of emergency vehicles travelling to their destinations where they are urgently needed; wasted fuel, increasing air pollution and carbon dioxide emissions owing to increasing idling, acceleration and breaking of vehicles; wear and tear on vehicles as a result of idling in traffic and frequent accelerating and breaking, leading to more frequent repairs and replacement of car parts; stressed and frustrated motorists, encouraging road rage and reduced health of motorists [2]. In China, the August 2010 China National Highway 110 traffic jam in Hebei province, is considered the world's worst traffic jam ever, as traffic congestion stretched more than 100 kilometres (62 miles) from August 14 to 26, including at least 11 days of total gridlock [3-5]. Traffic congestion on Adama roads is becoming an ever-present nightmare for road users, negatively affecting productivity and the environment. The city of Adama has spread out over the past years. Being the second largest city in Ethiopia, it is experiencing rapid urbanization and accelerated population growth and an exploded traffic on its roads. Nowhere is this more evident than in the Central Business District (CBD) and on other arterial roads. The current study therefore aims at applying a system of linear equations to traffic flow for a network of four one-way streets in Adama, Ethiopia. It also aims to determine the number of vehicles that should be allowed to route the four one-way streets under study in the model in order to reduce traffic congestion in Adama.

Mathematical Model: A system of linear equations was used to analyze the flow of traffic for a network of four one-way streets in Adama, Ethiopa. The pioneering work done by Gareth Williams on Traffic flow [6] has led to greater understanding of this research. The variables *a, b, c* and *d* represent the flow of the traffic between the four intersections in the network. The data was obtained by counting the number of vehicles that travelled around the four one-way streets between the hours of 6am to 10pm and 2pm to 6pm during the mid-week peak traffic hours. The arrows in the diagram indicate the direction of flow of traffic in and out of the network that is measured in terms of number of vehicles per hour (vph). The diagram in Figure 1 below describes the four one-way streets in Adama under study in the model:

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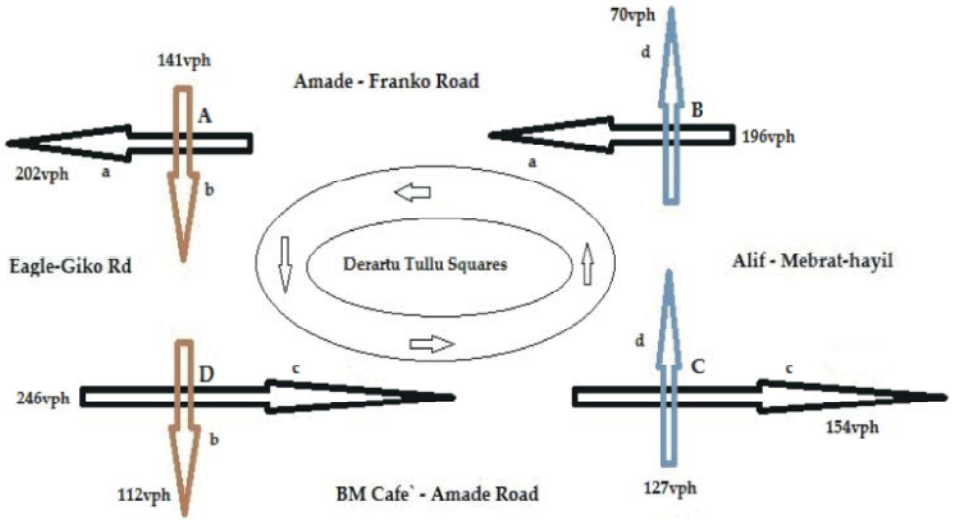

Fig. 1: Diagram of the four one-way streets, in Adama

Model Assumptions: The following assumptions were made in order to ensure the smooth flow of the traffic;

- Vehicles entering each intersection should always be equal to the number of vehicles leaving the intersection.
- The streets must all be one-way with the arrows indicating the direction of traffic flow.

The system of equations for the model was formulated as follows:

At intersection A: Traffic in = a + b, traffic out = 202 + 141, thus, a + b = 343.
At intersection B: Traffic in = 196 + 70, traffic out = a + d, thus, a+ d = 266.
At intersection C: Traffic in = c + d, traffic out 154 +127, thus c + d = 281
At intersection D: Traffic in 112 + 246, traffic out = b + c, thus, b + c =358.

The constraints were written as a system of linear equations as follows:

$a + b = 343$, $a + d = 266$, $c + d = 281$, $b + c = 358$

We then used the Gauss-Jordan elimination method to solve the system of equations. The augmented matrix and reduced row-echelon form of the above system are as follows:

$$\begin{bmatrix} 1 & 1 & 0 & 0 & 343 \\ 1 & 0 & 0 & 1 & 266 \\ 0 & 0 & 1 & 1 & 281 \\ 0 & 1 & 1 & 0 & 358 \end{bmatrix} \sim \begin{bmatrix} 1 & 0 & 0 & 1 & 266 \\ 0 & 1 & 0 & -1 & 77 \\ 0 & 0 & 1 & 1 & 281 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

The system of equations that corresponds to this reduced row-echelon form is;

$a + d = 266$, $b - d = 77$, $c + d = 281$

Expressing each leading variable in terms of the remaining variable, we had

$a = -d + 266$, $b = d + 77$, $c = -d + 281$

If we take a construction limit on Alif – Mebrat-hayil Rd (d) to be 50 vph, then the values of a, b and c will be;

$a = -50 + 266 = 216$ vph
$b = 50 + 77 = 127$ vph
$c = -50 + 231 = 181$ vph

RESULTS AND DISCUSSION

The system of the modeling equations has many solutions and therefore many traffic flows are possible. A driver has a certain amount of choice at the intersection, due to the nature of the model. Considering the stretch DC, it is desirable to have small traffic flow c as possible along this stretch of road. The flows can therefore be

controlled along the various branches by the use of traffic lights. According to the model, the third equation in the system shows that *c* will be a minimum when *d* is as large as possible, as long as it does not exceeds 281. The largest value *d* can be assumed without causing negative values of *a*, or *b* is 266.

Thus the smallest value of *d* is -266 + 281 or 15. Any road work on BM Cafe' to Amade Market Road down should allow for traffic volume of at least 15vph. Therefore, to keep the traffic flowing 181vph must be routed between D and C, 216vph between B and A and 127vph between the intersections A and D.

CONCLUSION

We have established that traffic congestion at the four one-way street linking Amade - Franko Rd, Alif – Mebrat-Hayil Rd, BM Café' – Amade Market Rd and Eagle - Giko Rd can be minimized if any road work on Alif – Mebrat –Hayil Rd should allow for traffic volume of at least 15vph. Therefore, to keep the traffic flowing 181vph must be routed between D and C, 216vph between B and A and 127vph between the intersections A and D respectively

Recommendations: In order to reduce the impact of traffic congestion and ensure the free flow of traffic in Adama, we made the following recommendations to the stakeholders of Adama:

- Provide exclusive lanes for public transport
- Use regulations and traffic engineers to control the traffic
- Ensure the use of innovative ideas to reduce traffic impacts on public transport.
- Provide traffic lights at the four intersections under discussion and adjusted in the direction of the results of this research.

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