Design and Evaluation of the Traffic Signal Light Control to Reduce the Vehicle Waiting Time

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Abstract

This paper examines the method for traffic network signal flow control design and evaluation of effective labelled signal light control for vehicle flow each direction. Network flow model is used to solve the traffic light management system. Here consider a traffic flow signal light model connected at two lanes, referred to as the intersection point, which permits parallel vehicle moments at the intersection without incurring an accident. The parameter assumptions are controlled by the weight of the traffic signal system and traffic volume. The proposed design for total flow in each direction begins with the conditions required to reduce the total waiting time in all directions. Finally, analyze the systems performance and get a hold for future estimate of vehicle flow in the traffic network. A numerical example is provided.

Keywords: *Crossroad junction; Path flow; Linear Programming Problem, Correlation; Prediction; Signal direction*

1. Introduction

Mathematical modelling develops mathematical symbol representations of certain observable factors to take the parameter into account. The decision-making parameters related to the problem are easily generated during the process. If a parameter is developed the current system can be modified and obtain. Due to the processing time of the evaluation process, new insights are considered as additional factors for the solution algorithms; however the success of the model is not independent on how effortlessly it is used and predicts the exact level of the future. In addition a mathematical explanation for a problem in the real-world can be very useful for analyzing system performance and assessing that problem. Everyone has experienced the caused by road traffic and expects immediate service. However, the current system does not support such system. Vehicle growth is due to many parameters such as road infrastructure, time, speed, vehicle capacity etc. Here, the traffic signal is considered as a problem and plays a key role especially in terms of traffic impact. If the arrangement of traffic parameters is not optimal, then it may be increased with an accident. The location of traffic lights at the junction of cross road is planned to facilitate the movement of vehicle flow. Therefore vehicles should not obstruct the obtainable flow. On the other hand, it is certainly compared that the congested traffic roads concrete volume is greater than the specific cross roads. In this case, performance of the Traffic congestion system is not effective. Here, we examine the vehicle flow direction. The crossroads junction area can move efficiently and in a straight line in two different directions. If the flow of traffic volume is even greater, it can be converted in to a mathematical branch. The mathematical model can easily give a possible solution. Recently, numerous researchers revealed different results. [9] has proposed a mathematical model for TSSP and adapted the MILP traffic signal to the NLP method to optimize the scheduled time. The algorithm of the proposed model is equivalent to the traffic signal control schemes optimized due to the fixed time relative to the total queue length. [6] Discussed the cross-road junction area and considered a random process model for multi-vehicle speed and distribution time, first collecting data during peak hours in Singapore. The NLP model was then generated based on the collected regarding the capabilities of the various vehicles. The duration of a traffic signal time is estimated using a statistical method. [1] Considered a dynamic traffic flow in urban and freeway networks. During this time, the types of methodology, advantages of computation and system performance were analyzed. [4] Developed in real time precision level of transport model such as dynamic transport model signal algorithm were developed to distribute vehicle flows evenly based on population density, while looking to avoid malnutrition and stagnation conditions. The model includes variables such as the length, quality and speed to determine its capacity. However, the traffic signal setting [8] published the first article on TMS and [5] developed the computational software tool (TRANSYT) to calculate the optimal traffic signal time and system performance. **[**2**]** Proposed a TCS tool for traffic management and analyzed the most effective signal path to the TCS junction area. **[3]** Models in the ITSCP were studied for the Multi-Dominant approach, because vehicle flow connections in a complex problem can be considered as human behavior, network models, risk, traffic demand, etc. [7**].** The difficulties of the ITSCP model depend not only on the crossroads arrival vehicle, but also by the number of intersections, vehicle preferences and vehicle types depending on the network. Here, we have considered the network flow model and how it can be applied to fix the traffic light management system. If the vehicle can move the flow horizontally at the intersection without risk, the pattern of traffic signal flow to both lanes is indicated as the intersection point. The vehicle flow at the intersection can be moved parallel without causing an accident. Consider the factor of limitation by the traffic volume and the weight of the traffic signal system. The proposed design for the total flow time in each direction begins with the condition that must be met in order to reduce the total waiting time in all directions. Finally, analyze system performance and forecast vehicle flow in the traffic network.

2. Model and Methodology

The aim of this paper is to define a mathematical model for the intersection traffic flow system of the traffic management distribution problem and to obtain an effective green time for vehicle flow in each direction. Traffic has not been distributed directly on the network. Mathematical modelling on the intersection traffic flow system and obtaining an effective green time. Model of the traffic signal flow connected to the two-flow path referred to as the intersection point. Consider the factor of limitation by the traffic volume and the weight of the traffic signal system.

2.1 Signal light distribution

This model predicts that the labelled points are controlled by traffic signal lights, $a,b,c,d,e,f,g \text{ and } h$ each of which is colored green, yellow and red as follows Fig:1 Traffic flow Model. The traffic path generally considers as the traffic flow of traffic that is expressed by the node is called edges, because the flow is connected by two edges but does not crash with the other flows. Initially identify the possible intersection direction are allowed to enter the intersection area. (i) Consider the current index (A1) of the left turned flow which should be followed by intersect on with current flow (D1) (ii) Current

index of left turned flow (D2 & A2) does not intersect the flow of (B1 & C1) Identify the various signal flow directions.
(i) Make different initial flow (ii) Make available preliminary assumptions, such as the flow of left turned signal
(iii) Whether the present left turned signal flow that has the same end vertices as the previous one (A1 & D1 man not runs parallel, but the flow D2 & B1 with B2& C1 it may be run in parallel) (iv)Express each flow with associated node on the networks (v) Associate two nodes on the signal networks by an edge, if and only if the consecutive flow represented by well-matched the two connected intersection's nodes is intimate the part of system and it can be defined as the one place to another place for two more intersection roads for traffic management networks. The resolution of intersection junction reduces conflict among the drivers to minimize and provides unlimited security for the movement of traffic vehicles. Traffic management system contains many parameters in order to analyze the traffic signal system. Here, some important parameters have been discussed because they are related to mathematical modeling as follows:
Flow Volume: The cumulative number of arriving vehicle passing through the time to the convinced intersection node.
Flow Density: The cumulative number of arriving vehicles that is inside the convinced node of road length generally communicates the vehicle unit per kilometre (v/km)
Optimize the performance of intersection junction between (i) using the maximum number of vehicle in the concerned node is called flooded flow traffic. The vehicle capacity is based on the limitation of the intersection roads as per hour, but the flow is not same for the intersection roads because it slightly exaggerated the flow rate: (a) Traffic arrangements. (b) Increase the frequency of occurrence at each intersection junction (c) radius (d) will be turned to the right ran into enter from the opposite direction.
Phase: It is part of the traffic signal light cycle length; it can be allotted to the perfect assignment of traffic flow movements. It will be divided into several parts by the sub flows.

2.2 Possible Flow Directions

Traffic flow direction must be followed by the labelled points as follows:
1) Flow A1 = (A2, D2, B2, C1, C2), 2) Flow A2 = (A1, D2, B2), 3) Flow D2 = (A1, A2, D1, D2, B1, C1, C2) 4) Flow D1 = (D2, ,C1, C2), 5) Flow B2 = (A1, A2, D2, B1, C1), 6) Flow B1 = (D2, B2, C1), 7) Flow C1 = (A1, D2, D1, C1)
The hypotheses of the intersection junction character are as follows:
1) Does not follow the flow of the right turn into the left turn. Because the waiting time for the flow of moving time is zero
2) The remaining left flow nodes A1 & C1 are moving based on the traffic signal.
Here A2, D1, B2 & C2 are the straight flow nodes and three turn left flows are A1, D2, & C1 and one flow turn right is B1. Two paths are connected by the node if flows are parallel to link the consecutive points. Therefore, organized the optimal control of traffic signal intersection road traffic management system is to avoid the accident and minimize the total waiting time. The interval time for each initial direction should be followed by the current location otherwise it is not considered. The different waiting time possibilities for each flow (R & G) are discussed as follows: The one week's real time data's is collected at the Solinganallur junction during the period 7 a.m to 8 a.m. Collected data's is split into every 10 mins and set the service time for every cycle of 600 secs. It is assumed every sec provides the service for 2 vehicles. Arriving vehicles are not restricted. Calculate the total waiting time and reduce the waiting for existing and proposed methods.

2.3: Data Collection Data was collected in a busy road traffic intersection during peak hours for a one month period. The number of vehicles passed by, time, phase of the intersection, day at the week and cycle time are the key parameters that were taken in for detailed collection and study.

Table: 1 The total number of vehicles arriving from the each direction

Date	Time	Red Signal Duration/Cycle	Green Signal Duration for the direction	N-S	W-E	S-N	E-W	Total No.of Vehicles
06-02-2022	7 am to 8 am	450	600	112	196	151	113	572
				151	226	172	122	671
				182	244	202	154	782
				196	241	202	166	805
				184	222	191	157	754
				179	208	183	149	719
06-03-2022	7 am to 8 am	450	600	279	302	247	221	1049
				282	302	254	221	1059
				277	289	245	219	1030
				281	299	256	211	1047
				278	299	245	213	1035
				249	278	202	177	906
				116	179	129	111	535
06-04-2022	7 am to 8 am	450	600	191	162	177	141	480
				189	202	166	133	501
				188	221	166	142	529
				187	211	203	167	581
				195	233	181	176	590
				189	241	193	159	593
				141	155	123	100	519
06-05-2022	7am to 8 am	450	600	129	145	110	91	475
				123	139	119	89	470
				131	165	129	88	513
				133	166	98	88	485
				124	109	89	81	403
				109	187	154	97	547
06-06-2022	7am to 8am	450	600	146	171	123	95	581
				134	167	112	91	568
				136	166	111	84	592
				129	141	134	111	597
				133	129	113	86	537

		123	131	104	92	526

Table:2 Maximum significant vehicle flow level for each direction

Marginal	Information for sub flow	Waiting time	Moving time	Total time
Before Divider	Total flow	450	150	600
After Divider	Flow P = (A1,A2,D2), Q=(D2,D1,C1,C2) R = (B1, C1, D2)	200	400	600
	Flow P = (A1,A2,D2), Q= (B1, B2, D2) R=(D2,D1,C1, C2)	250	350	600
	Flow P=(A1,A2,D2,D1), Q=(B2,B1,C1,D2) R=(D2,D1,C1, C2)	300	300	600

The above flow is only considered as the straight direction, but it's possible to the traffic management system, because in this duration it may be possible to turn left or right, so we can arrange the actual traffic vehicle flow volume of the intersection cross road based on the possibilities of the path combinations. So, assumptions may ignore the number of vehicles passing in each of the existing and time intervals are uniformly created. So, to avoid the waiting time of the total arriving vehicle given by the different weights

3 Traffic Signal Parameters Assignmen

Traffic flow time setting at an intersection junction has an equal length and equal weight for each flow. The existing flow time is longer than the somewhat quiet flow, such as the existing flow to the turn right or left by the vehicle dense. In the traffic network, the four roads that go straight are connected to C2 otherwise flow for the turn on left or right. While assigned the interval variable as per the direction as follows:

$$A2 \to x_1,\ D1 \to x_3,\ B2 \to (x_1 \,\&\, x_2),\ C2 \to (x_3),\ A1 \to x_1,\ D2 \to (x_1, x_2, x_3) \qquad (1)$$

The mathematical model of the above network model objective function

$$Z = \delta_1 (2x_1 + x_2 + 2x_3) + \delta_2 (2x_1 + 3x_2 + 2x_3) \qquad (2)$$

Subject to the constraint as follows:

$$x_1 + x_2 + x_3 = 600,\quad x_1 \ge 150,\quad x_1 + x_2 \ge 150,\quad x_2 \ge 150,\quad x_3 \ge 150,\quad x_1 + x_2 + x_3 \ge 150 \qquad (3)$$

Table:3 Initial flow time

	Time		
Marginal	Red light	Green light	Total
(A1, A2)	145	205	350
(B2)	133	217	350
(C1)	218	132	350
(D1)	225	125	350
(D2, B1)	225	125	350
Total	946	804	

Now, split the actual vehicle at each intersection junction table as follows:

Table: 4 Flow index

No	Flow Index	Actual Traffic flow for certain time
1	A_1	112
2	A_2	151
3	B_1	112
4	B_2	252
5	C_1	196
6	C_2	271
7	D_1	113
8	D_2	252
Total		1459

The calculated traffic flow for each direction is as follows:

S_{NS} = (263/1459) = 0.18 x 100 = 18, S_{WE} = (309/1459) = 0.2117 x 100 = 21.11,

T_{LR} = (748/1459) = 0.5125 x 100 = 51.26

The objective function of max flow

$$z = 18 S_{NS} + 21.11\, S_{WE} + 51.26 T_{LR} \tag{4}$$

By the data, the current minimal flow is 400 second. The total flow of green light is 804 seconds.

The construed new model for the above problem is as follows:

$$z = 18 S_{NS} + 21.11\, S_{WE} + 51.26 T_{LR} \tag{5}$$

Subject to the constraints

$$S_{NS} + S_{WE} + T_{LR} = 804,\ S_{NS} \geq 120,\ S_{NS} + S_{WE} \geq 120,\ S_{WE} \geq 120,\ S_{WE} + T_{LR} \geq 120,\ T_{LR} \geq 120,\ S_{Ns} + S_{WE} + T_{LR} \geq 120 \tag{6}$$

Using Tora Software, we can get the optimal value of the traffic flow direction is $x_1 = 19,\ x_2 = 8,\ x_3 = 9$.

The objective function value is 972.22 ≈ 972

Using M/M/1 infinite queuing model to using XLStat, calculate the predicate number of passing vehicle and calculate total waiting time of the traffic length is

Table:5 Queue length for each direction

Lq1	Wq1	Lq2	Wq2	Lq3	Wq3	Lq4	Wq4	Lq	Wq
0.165188	0.331852	0.50589	0.580741	0.30026	0.447407	0.168151	0.334815	1.13949	1.694815
0.30026	0.447407	0.672606	0.66963	0.389584	0.50963	0.196003	0.361481	1.558453	1.988148
0.436201	0.539259	0.784013	0.722963	0.537337	0.598519	0.312309	0.456296	2.06986	2.317037
0.50589	0.580741	0.764853	0.714074	0.537337	0.598519	0.362877	0.491852	2.170956	2.385185
0.44584	0.545185	0.649007	0.657778	0.480408	0.565926	0.324596	0.465185	1.899852	2.234074
0.421939	0.53037	0.569732	0.616296	0.441007	0.542222	0.292359	0.441481	1.725037	2.13037
0.591855	0.628148	0.876563	0.764444	0.660754	0.663704	0.480408	0.565926	2.60958	2.622222
1.025067	0.826667	1.20104	0.894815	0.803411	0.731852	0.643174	0.654815	3.672691	3.108148
1.04723	0.835556	1.20104	0.894815	0.849593	0.752593	0.643174	0.654815	3.741037	3.137778
1.010423	0.820741	1.099865	0.856296	0.790453	0.725926	0.631585	0.648889	3.532326	3.051852
1.039816	0.832593	1.177297	0.885926	0.863026	0.758519	0.586285	0.625185	3.666423	3.102222
1.017732	0.823704	1.177297	0.885926	0.790453	0.725926	0.597452	0.631111	3.582933	3.066667
0.816474	0.737778	1.017732	0.823704	0.537337	0.598519	0.412563	0.524444	2.784105	2.684444
0.480408	0.565926	0.3456	0.48	0.412563	0.524444	0.261807	0.417778	1.500379	1.988148
0.4704	0.56	0.537337	0.598519	0.362877	0.491852	0.232942	0.394074	1.603556	2.044444
0.465435	0.557037	0.643174	0.654815	0.362877	0.491852	0.265534	0.420741	1.737021	2.124444
0.460497	0.554074	0.586285	0.625185	0.54267	0.601481	0.367263	0.494815	1.956714	2.275556
0.500741	0.577778	0.714917	0.69037	0.431421	0.536296	0.407914	0.521481	2.054993	2.325926
0.4704	0.56	0.764853	0.714074	0.490522	0.571852	0.332919	0.471111	2.058693	2.317037
0.261807	0.417778	0.316379	0.459259	0.19923	0.364444	0.131687	0.296296	0.909103	1.537778
0.219141	0.382222	0.276872	0.42963	0.159342	0.325926	0.10905	0.26963	0.764405	1.407407
0.19923	0.364444	0.254433	0.411852	0.186482	0.352593	0.104309	0.263704	0.744454	1.392593
0.225988	0.388148	0.358519	0.488889	0.219141	0.382222	0.101979	0.260741	0.905626	1.52
0.232942	0.394074	0.362877	0.491852	0.126472	0.29037	0.101979	0.260741	0.82427	1.437037
0.202482	0.367407	0.156458	0.322963	0.104309	0.263704	0.0864	0.24	0.549649	1.194074
0.280705	0.432593	0.385067	0.506667	0.19923	0.364444	0.118848	0.281481	0.983849	1.585185
0.236458	0.397037	0.367263	0.494815	0.165188	0.331852	0.10905	0.26963	0.877959	1.493333
0.243569	0.402963	0.362877	0.491852	0.162252	0.328889	0.092919	0.248889	0.861616	1.472593
0.219141	0.382222	0.261807	0.417778	0.236458	0.397037	0.162252	0.328889	0.879658	1.525926
0.232942	0.394074	0.219141	0.382222	0.168151	0.334815	0.097396	0.254815	0.71763	1.365926
0.19923	0.364444	0.225988	0.388148	0.142433	0.308148	0.11146	0.272593	0.679111	1.333333
0.273067	0.426667	0.436201	0.539259	0.186482	0.352593	0.129067	0.293333	1.024816	1.611852

0.273067	0.426667	0.465435	0.557037	0.196003	0.361481	0.11146	0.272593	1.045965	1.617778
0.254433	0.411852	0.385067	0.506667	0.183361	0.34963	0.150769	0.317037	0.97363	1.585185
0.24	0.4	0.421939	0.53037	0.180267	0.346667	0.139707	0.305185	0.981913	1.582222
0.261807	0.417778	0.19923	0.364444	0.159342	0.325926	0.080119	0.231111	0.700497	1.339259
0.243569	0.402963	0.186482	0.352593	0.116359	0.278519	0.088547	0.242963	0.634956	1.277037
0.147964	0.314074	0.209067	0.373333	0.129067	0.293333	0.092919	0.248889	0.579016	1.22963
0.165188	0.331852	0.243569	0.402963	0.142433	0.308148	0.101979	0.260741	0.653169	1.303704
0.177198	0.343704	0.250785	0.408889	0.1536	0.32	0.104309	0.263704	0.685893	1.336296
0.186482	0.352593	0.232942	0.394074	0.116359	0.278519	0.088547	0.242963	0.624329	1.268148
0.156458	0.322963	0.19923	0.364444	0.095144	0.251852	0.090719	0.245926	0.541551	1.185185
0.168151	0.334815	0.276872	0.42963	0.129067	0.293333	0.104309	0.263704	0.6784	1.321481

Table:6 Path flow Predictions

Variable	Mini	Max	Mean	Std. deviation
Queue Length(Lq)=N1^2/(O1*(O1-N1))	-602.002	598.002	0.488	53.136
Waiting Time(Wq)=N1/(O1(O1-N1))	-1.002	0.998	0.002	0.089

Table:7 Regression for Queue Length

Regression of variable Queue Length(Lq)=N1^2/(O1*(O1-N1)):	
Goodness of fit statistics (Queue Length(Lq)=N1^2/(O1*(O1-N1))):	
DF	2152
R^2	1.000
Adjusted R^2	1.000
MSE	0.077
RMSE	0.277
MAPE	6.821
DW	0.165
Cp	2.000

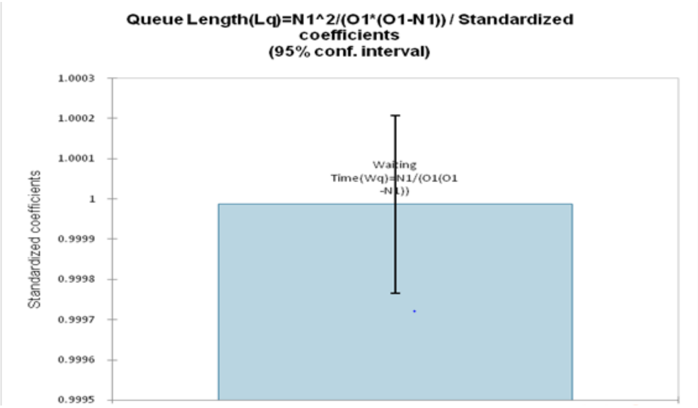

Fig 2 Queue length

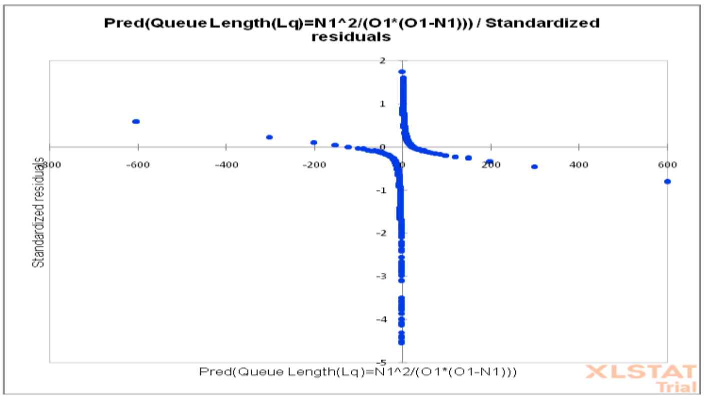

Fig 3 Regression Queue Length

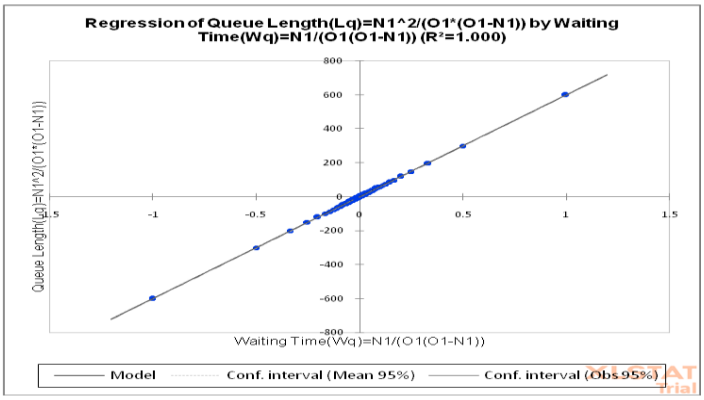

Fig 4 Queue Length Prediction

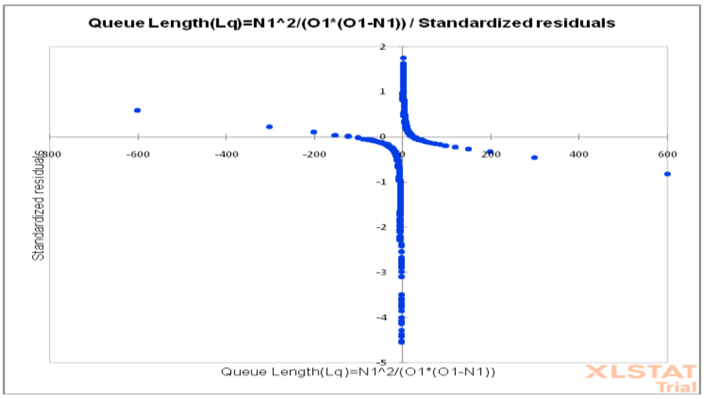

Fig 5 Standard Residual Queue Length

4. Conclusion

In this paper, proposed a dynamic signal time distribution for the each direction in crossroad junction area. The proposed method includes the Linear Programming (LP) technique and Statistical methods for the prediction of traffic flow. Experimental results show that LP and Statistical methods have greater capabilities to provide better solutions in road traffic management systems. The statistical methods in the current road traffic scenario give a clear picture. The merits of signal time distribution plans over static signal plans are clearly defined. The proposed method is statistically proven effective, saves a lot of time, and gives passengers equal opportunity. The dataset used to train the model and evaluate the results was not large in size. A large dataset can produce a higher accuracy rate and better results. In future, the proposed work can be tested with a larger dataset to attain better performance. Prioritizing path for emergency vehicle can be considered as another opportunity for future work.

5. Results and Discussion

This paper examines considers the network flow signal system and model that have been linked to the traffic signal light at the crossroads junction area. The Linked line path was divided into different parts of possible directions and provided the vehicle path flow. Develop the traffic light signal model through linear programming and resolve the optimal traffic flow in each direction. The result was compared with the existing model to increase the vehicle flow time (minimize the waiting time) for the proposed model: table (i) 400 seconds for the vehicle flow time but proposed algorithm 804 seconds and objective function value was 972 .This network flow model generates distinctive signal control for the labeled flow direction (NS, SE, LR) and reaches the objective level. This model helps towards improving the efficient traffic flow of the traffic light signal control system. It is clear that the proposed model provides a better solution than the network traffic flow model. The advantages of these signal schemes over standard signal schemes are clearly explained. The method of creating the proposed signal scheme is statistically proven. It saves time, the economy and provides equal opportunity.

6. References

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