Acceleration Noise Parameter Measurement At Signalized Intersections in Mosul City

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Abstract

In this study a parameter called traffic acceleration noise along different approaches of some signalized intersections located within the Mousl City road network was measured. This parameter is usually defined as the root mean square of car acceleration. Approaches of two signalized intersections having four legs were surveyed different times using digital camera to measure vehicle speed at the start of green light opening. Acceleration noise correlated with other signal parameters obtained out of the analysis of different phasing plans such as, saturation flow, v/c ratio, lane group volume .etc., level of service is obtained too. Outcomes out of this study are the development of a new scale measure for level of service depending on acceleration concept rather than approach delay concept as demonstrated by the Highway Capacity Manual Special Report 209 authorized methodology.
Key Word: Noise, Mosul City

قياس معامل اضطراب التعجيل ألمروري في التقاطعات ألمسيطر عليها بإشارات ضوئية في مدينة ألموصل

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الخلاصة

في هذه الدراسة تم قياس معامل يدعى ضوضاء التعجيل المروري على طول المقتربات المختلفة لبعض التقاطعات العاملة بالإشارات الضوئية الواقعة ضمن شبكة الطرق في مدينة الموصل هذا المعامل يعرف عادة بأنه الجذر ألتربيعي لتعجيل المركبة. تم اختيار مقتربات ضمن تقاطعين من نوع ذات الأذرع الرباعية تم عمل مسح لسرع المركبات باستخدام كاميرات رقمية عند بداية انفتاح الاشارة الخضراء. تم عمل ارتباط بين معامل الضوضاء المروري مع معاملات الإشارة الضوئية بعد القيام بتحليل الأطوار المختلفة للإشارة الضوئية مثل جريان الإشباع ، نسبة v/c وحجم المجموعة الاتجاهية مع مستوى الخدمة كانت نتائج هذه الدراسة هي استنباط مقياس جديد لمستوى الخدمة اعتمادا على مبدأ التعجيل كبديل عن مفهوم زمن التأخير والمعتمد حاليا" من قبل دليل الاستيعاب للطرق التقرير الخاص المرقم 209 حسب طريقته.

الكلمات الدالة:ـ مدينة الموصل، ضوضاء

Background and Scope:

Jones and Potts, as the standard deviation of the acceleration record over a given test, defined the acceleration noise of a vehicle section given by the following equation:

$$\sigma = \sqrt{1/T \int_0^T \left(A(t) - Aav\right)^2 dt} \qquad \text{......(1)}$$

Where

Aav = Average acceleration of vehicle measured during a period of (t) in   seconds.

σ = acceleration noise.

T = total period of study in seconds.

A(t) = acceleration of vehicle measured at any period of (t) in seconds.

Acceleration noise has been independently related to individual driver satisfaction environment inside the car and safety, since more hazardous roads were observed to have higher σ (1, 1962).

Herman, et al.(2, 1962), introduced the concept of acceleration noise as an additional term in their car – following laws, this traffic parameter proves of great interest in its own right. It helps to give answers to many important questions concerned with qualitative aspects of traffic theory, aspects that are difficult to describe in quantitative terms .Typical of these questions were those seeking to compare the various interrelated effects of road, driver, and traffic conditions, effects that all contributed to general traffic phenomena.

Helly,W, and Baker P,C, (3, 1967). modified the calculation of acceleration noise by proposing a parameter (G), as a velocity gradient .

G= σ / v   ………(2)

Where

σ =acceleration noise, and.

v= mean velocity on the trip.

It was reasoned that the acceleration noise alone does not describe the quality of the trip, that a fast trip and a slow trip could both have the same value of σ , but the fast trip would be more desirable.

Total acceleration noise of vehicles at different locations in a platoon has been measured by Herman, and Rothery (4 , 1965). They noted that, traffic has broadened the acceleration distribution function so that the acceleration noise far down the platoon was about three times that of the leader car, which is effectively moving freely on the road. Traffic broadening was not large for smoothly flowing traffic, but the dispersion increases rapidly at the onset of congestion.

In this study, the signalized intersections selected are the most congested locations to serve hundreds of vehicles per hour moving in the four directions of flow to take an opinion about the smoothness of traffic using different approaches of each intersection. Signal operations recorded during data collection stage have been analyzed and different parameters of phasing like, approach delay time, volume/ capacity ratio (i.e, v/c ratio), lane group capacity, saturation flow, percentage of heavy vehicles, etc.. have been correlated to acceleration noise parameters to conclude how this parameter could effect the quality of flow. Flow quality have been assessed by level of service concept (i.e , LOS) and proposed by the different authors like the Institute of Traffic Engineers (5, 2000) .

Data collection:

In this study, there were three types of data collected on each of the two signalized intersections approaches. The two signalized intersections were AL-MUTHANA, and AL-SUES intersections located within Mousul City suburban road network as shown in figure (1).

Figure (1, A): Layout of Al-Sues Signalized Intersection Considered in the Study

Figure (1, B): Layout of Al-Muthana Signalized Intersection Considered in the Study

Data types are as follows:
1- Signalized intersection data includes:
  i- geometric design of intersection
  layout data such as:
   1- number of lanes
   2- lane width.
   3- grade of each approach.
   4- storage bay length at left turns.
   5- chanalization dimensions and location, and.
   6- presence of right turn filters:
  ii- traffic information such as:
   1- lane approach traffic volumes.
   2- lane group distribution.
   3- directional traffic volumes.

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4-   percentage of heavy vehicles.
5-   peak hour factors, and
6-   pedestrian, bus stops and bicycle flows
iii-   signalization information such as:

1- cycle length, green, red and yellow time periods for each phase.
2- phasing plan, number of phases and their distribution, and
3- pedestrian phasing and crossing times within the cycle.

The foregoing data was mostly collected manually during peak hour of flow which was selected between (7:30 – 9:30) A.M., during a weak day. Plane table, and tapes were mostly used to project the intersection layout. Other information not remarked here just used to satisfy the HCM methodology and to conduct a complete analysis for both intersections existing operations too.

2- Total acceleration noise data. This data was collected using a digital image camera installed at vantage point to cover maximum length of the intersection approach. Photography implemented during a period of green time or phase opening within a short period of time, until traffic platoon speed halt in order to estimate the accelerated traffic speed during full green phase . Out of this data, speed in (mph), and time in seconds had been plotted to find out speed range, and total period of time of photography for more than 60 cars starting after green light for each one of the 16 lane groups classified on both investigated signalized intersections. During this period, number of cars passing each shorter period of 2 seconds traced as one interval , this is shown from the sample of calculation and difference in speed occurred by the driver causing noise of speed change of (2 mph) for 12 intervals of them. This speed difference can be noticed in the equation given by Jones, Potts, and Drew   (1, 1962,6 , 1967), Which is:

$$\sigma = \{(\Delta U)2 \;/ \; T\sum ni^2 \;/\Delta ti - ((V_T - V_O)\;/\;T)^2\}^{1/2} \;........(3)\; \text{where}$$

σ = acceleration noise in (ft/ sec^2 .)

ΔU = standard speed change caused by driver due to some internal or external   action during approaching to signal equal to (2 mph). or (8.6 ft /sec^2.)

ni = number of cars passing within each 2 sec. interval.

T = total time of filming the platoon in seconds.

V_T = maximum substantial speed by a certain vehicle in the platoon in mph.

V_O = minimum sustained speed by a certain vehicle in the platoon in (mph) (i.e, $V_O = 0$ at traffic halt).

The term $(V_T - V_O)\;/T$ could be changed to ft/ sec^2. by multiplying the term by (5280/ 3600), as shown in the numerical example.

Δti = time interval taken to count the number of cars (ni) passing, which is constant taken as 2sec. The sum of this periods is equal to the total time of photography , (i.e, $\sum \Delta ti = T$). The term $(V_T - V_O)\;/T$, may be equal to zero if ($V_T = V_O$) in the platoon. This is true at long sections of road when speed becomes uniform. At intersection approach, this value is more important than uniform section operation.

Acceleration noise values obtained out of this measurement were synchronized with the signalization, or phasing condition within which approach value count took place. This is very important for data to be completely randomized and correlation to become closer to truth without confounding.
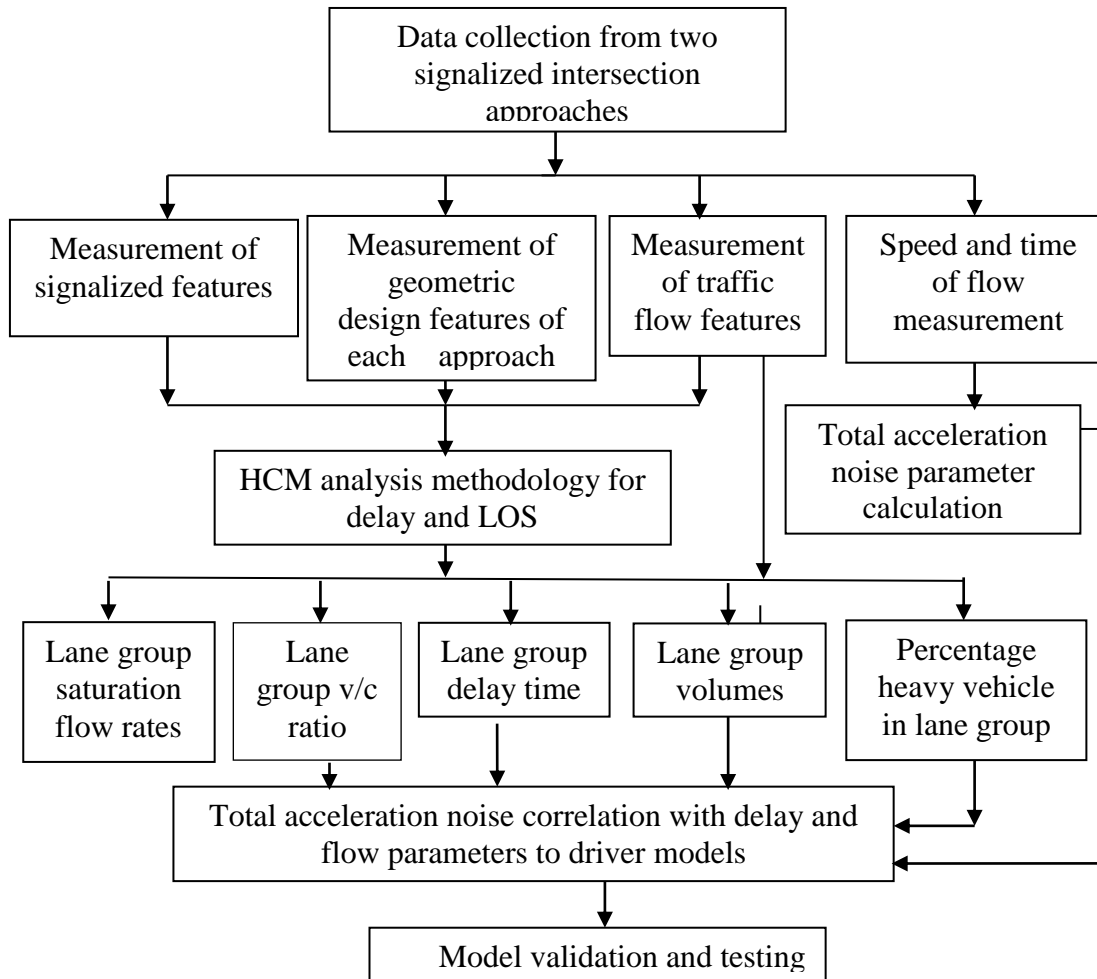
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┌─────────────────────────────┐
│   Data collection from two  │
│   signalized intersection   │
│        approaches           │
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| Measurement of signalized features | Measurement of geometric design features of each approach | Measurement of traffic flow features | Speed and time of flow measurement |

┌─────────────────────────────┐
│ HCM analysis methodology for │
│   delay and LOS   │
└─────────────────────────────┘

┌─────────────────────────────┐
│   Total acceleration   │
│   noise parameter   │
│   calculation   │
└─────────────────────────────┘

| Lane group saturation flow rates | Lane group v/c ratio | Lane group delay time | Lane group volumes | Percentage heavy vehicle in lane group |

┌───┐
│ Total acceleration noise correlation with delay │
│   and flow parameters to driver models   │
└───┘

┌─────────────────────────────┐
│ Model validation and testing │
└─────────────────────────────┘

Figure (2): Study Methodology Flow Chart.

Results and Discussion:

In this analysis total acceleration noise is considered as dependent variable, but other parameters obtained from the two signalized intersections analysis are considered as independent variables.

Total acceleration noise and lane group delay:

Effect of traffic delay on total acceleration noise behaved by the drivers is shown in figure (3). This trend is directly increasing and showing that more delay is resulting due to speed decrease. S-shaped function is the best model fitting this relationship with ($R^2 = 0.976$) and highly significant with F statistic on both 5% and 1% significance level. HCM gives a direct relationship between the six levels of service common on the methodology of signalized intersection capacity
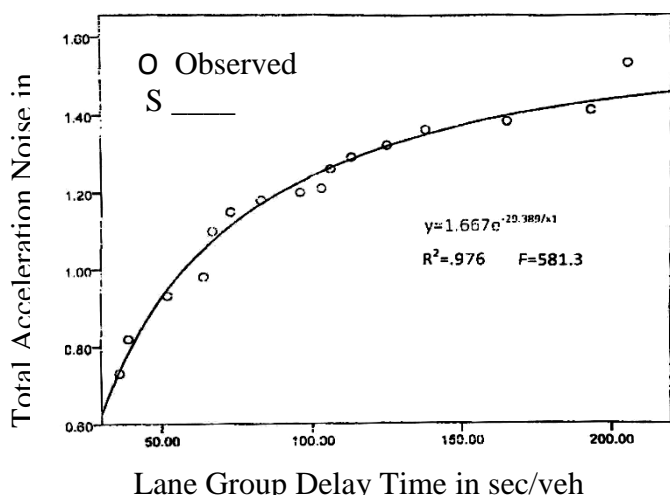

$y = 1.667 e^{-29.389/x_1}$

$R^2 = .976$ $F = 581.3$

Lane Group Delay Time in sec/veh

Figure (3): Effect of Lane Group Delay Time in sec/veh. On Total Acceleration Noise in m/sec^2 at Signalized Intersections

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analysis. Total acceleration noise can be used as a surrogate to evaluate approach level of service directly from measuring it in the field within a short period of time better than using the full HCM extensive methodology for any lane group approach, and the intersection as a hole. Table (1), gives the total acceleration noise values to be useful to evaluate LOS better than deep HCH analysis. The acceleration noise range values according to each range values of intersection control delay obtained from the HCM was interpolated from the empirical model resulted from the above analysis shown in figure (3).

Table (1): Levels of Service Criteria and Total Acceleration Noise in   m /sec^2 Resulted from This Study.

LOS	A	B	C	D	E	F
(HCM) control delay time in sec/veh (5)	≤ 10	>10-20	>20-35	>35-55	>55-80	>80
Total acceleration noise in m/sec^2 in this study	≤ 0.09	>0.09-0.38	>0.38-0.72	>0.72-0.98	>0.38-1.15	>1.15

Total acceleration noise and v/c ratio:

Figure (4), shows that the third degree polynomial model, which is the best fitting of data between acceleration noise parameter and v/c ratio. Correlation found in this fitting is not effective, (i.e. $R^2 = 0.26$), with F statistic less than required for good confidence on 5 percent level. In this study, traffic noise at signalized intersection is not going to regress with v/c ratio.

Total *acceleration noise, and lane group capacity:*

Figure (5), is showing the third degree polynomial model, which is best fitting the data between acceleration
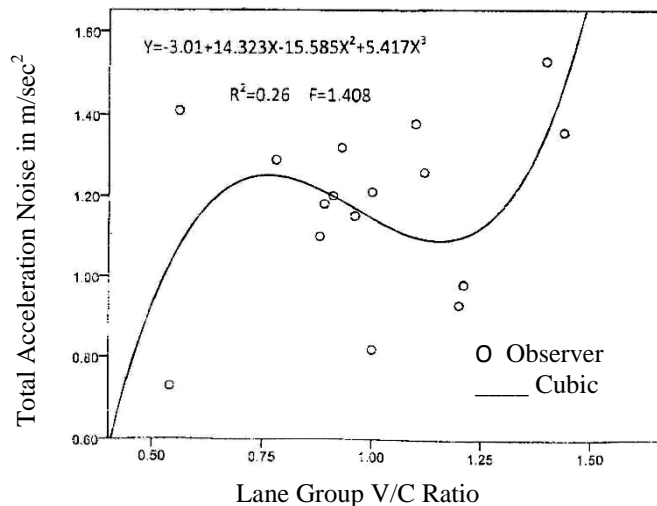
Figure (4): Effect of Lane Group V/C Ratio on the Total Acceleration Noise in m/sec^2 at Signalized Intersections

noise, and lane group capacity. F statistic obtained was highly more than required by statistical tables on 5 percent level of significance with acceptable correlation of ($R^2 = 0.828$) only. Lane group capacity increases and directly affecting the total acceleration noise as drivers will be more hesitated to navigate with their vehicles on this congested traffic flow environment. Total acceleration noise is going to be about constant after a lane group capacity of 750 pcph .

Total acceleration noise and lane group saturation flow rate:

Effect of saturation flow rate on total acceleration noise behaved by drivers is shown on figure (6). Second degree polynomial with weak ($R^2 = 0.498$) is best fitting the above function. F statistic obtained on 5 percent level of significance is controlling the acceleration

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of the above model according to statistical tables. The maximum total acceleration noise is obtained at 5000 pcphgpl saturation flow on four lane number group.
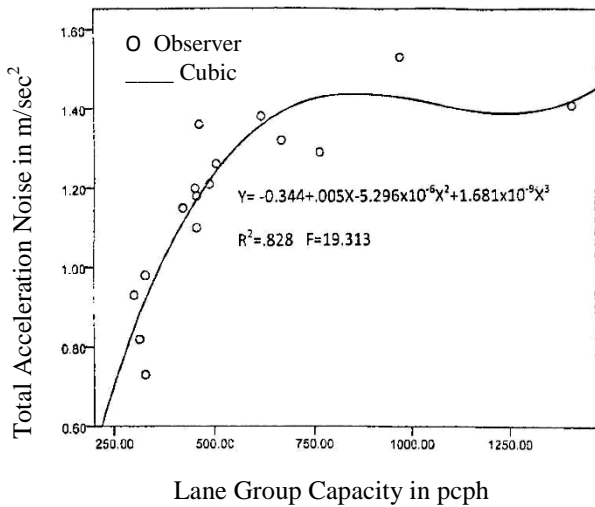

Figure (5): Effect of Lane Group Capacity in pcph on the Total Acceleration Noise in m/sec^2 at Signalized Intersections
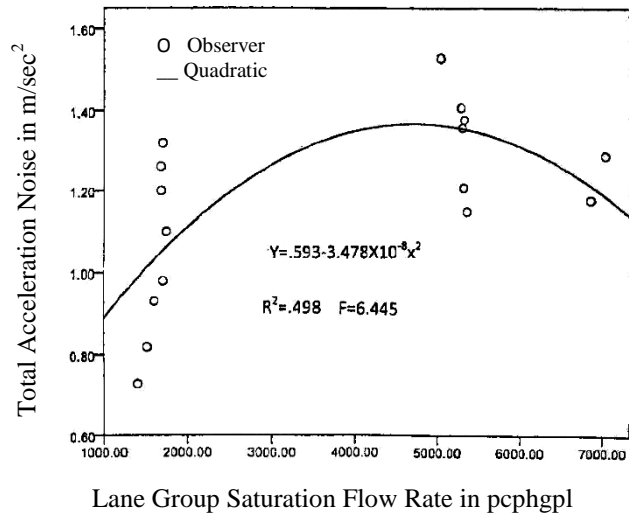

Figure (6): Effect of Lane Group Saturation Flow Rate in pcphgpl on the Total Acceleration Noise in m/sec^2 at Signalized Intersections

Total acceleration noise and lane group volume:

Total acceleration noise and lane group volume relationship is shown in figure (7). A peak value of total acceleration noise is obtained at lane group volume of 1000 vph as shown in the figure. It is clear that this relationship is directly proportional represented by the third degree polynomial model which is best fitting the above data . F statistic obtained is highly more than given by the statistical tables, assisting the acceptable coefficient at 95 percent level. Coefficient of determination R^2 of (0.916) obtained is reflecting the acceptability of the model.
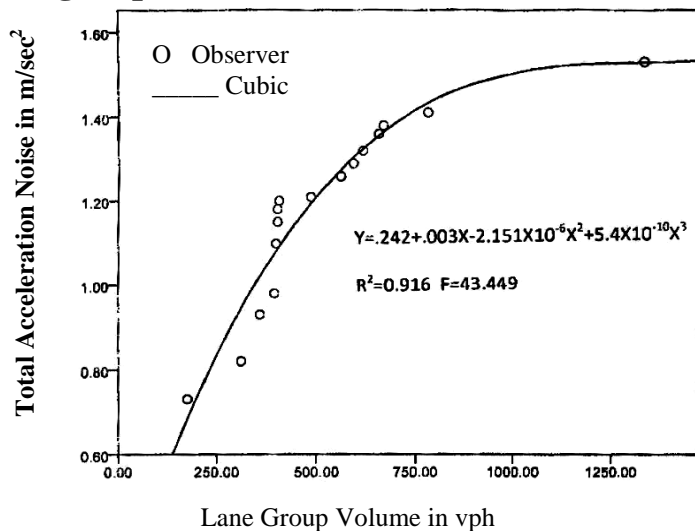

Figure (7): Effect of Lane Group Volume on the Total Acceleration Noise in m/sec^2 at Signalized Intersections

Total acceleration noise, and percentage heavy vehicles:

Total acceleration noise with percentage heavy vehicles relationship is directly increasing as trucks are going to enforce drivers to change their speeds at close driving on intersection approaches. This is shown in figure (8). Third degree polynomial model is best fitting this correlation with acceptable value of (R^2 = 0.705) only, but higher in confidence than other models tried in this analysis. F statistic obtained is highly greater than F obtained

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on 5 and 1 percent levels of significance which are (4.6) and (8.06) respectively. Minimum value of acceleration noise is obtained at 4 percent but maximum value is obtained at 10 percent of heavy vehicles in lane group flow. This reflects the driver tendency to change his/her speed with the above range in percentage of heavy vehicles.

Conclusion and
Recommendations:

According to the experimental data collected and designed to follow the methodology given, and results shown in this study. The following conclusions can be drawn out.

Figure (8): Effect of Heavy Vehicles in Lane Group on the Total Acceleration Noise in m/sec² at Signalized Intersections

$Y = 2.876 - 1.034X + .172X^2 - .008X^3$

$R^2 = .705$ $F = 9.566$

1- Total acceleration noise parameter could be used as an additional parameter to control delay time at signalized intersections to evaluate the LOS of lane group, approach, and intersection as a hole given by the HCM. This hypothesis is assisted by high R^2, and confidence level statistically accepted at 95 percent.
2- Total acceleration noise is highly correlated with most of the parameters describing the traffic flow condition on signalized intersection lane groups giving medium to high R^2 values.V/C ratio measure of effectiveness is the only parameter showing no correlation with acceleration noise parameter.
3- Third degree polynomial is the function mostly correlating total acceleration noise parameter with lane group capacity , lane group volume, percentage of heavy vehicles with acceptable confidence level, and medium to high correlation coefficient.
4- S-shaped and second degree polynomial functions are representing the variation of acceleration noise parameter with control delay time, and lane group saturation flow rates respectively. R^2 obtained are high, and medium acceptable values on 95 percent level of confidence.
5- Total acceleration noise is going to have approximately a constant value after a lane group capacity of 750 pcph.
6- Total acceleration noise parameter is showing a maximum value at saturation flow rate produced from green signal near 1250 pcphgpl.
7- Total acceleration noise is going to be constant at lane group volume of 1000 vph and more.
8- Heavy vehicles percentage range between (4-10) percent is giving the lowest, and highest values of acceleration noise of traffic at signalized intersection respectively .

Recommendations suggested in this study for further research are to be conducted on unsignalized intersections or, roundabout junctions to reflect their levels of service peak operation periods. Three, and four - legged unsignalized intersections can be concluded for further suggested study. Urban and rural unsignalized intersections operation levels can be evaluated using the total acceleration noise parameter as well.
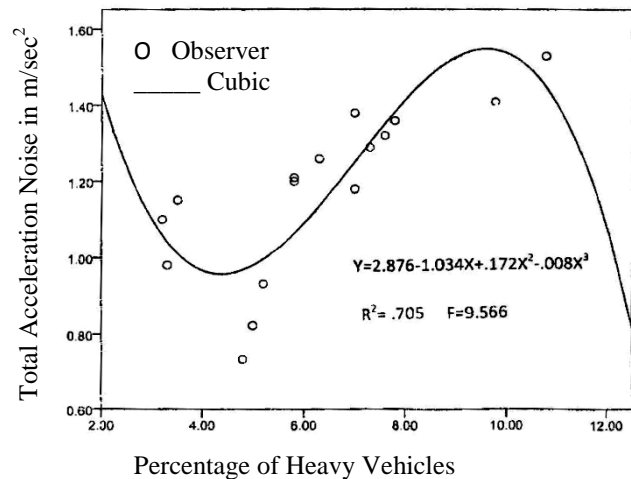
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Appendix (A)
Numerical Sample of Calculation of Total Acceleration Noise

Interval	Elapsed time at end of interval sec.	Velocity U at end of interval (mph)	ni	Δti(sec)	$ni^2 / \Delta ti$
0	0	0			
1	2	2.8	0	2	0
2	4	8.13	1	2	0.5
3	6	11.9	2	2	2
4	8	18.13	2	2	2
5	10	25	3	2	4.5
6	12	31.25	2	2	2
7	14	31.25	3	2	4.5
8	16	31.25	2	2	2
9	18	34.4	3	2	4.5
10	20	25	2	2	2
11	22	14.4	2	2	2
12	24	6.3	0	2	0
Total time	T = 24 sec.		22		$\sum ni^2 /\Delta ti=26$

$$\sigma = \left[\frac{8.6}{24} \ X \ 26 \ - \ \left(\frac{31.25-0}{24}\right)^2 \ X \ \left(\frac{5280}{3600}\right)^2\right]^{1/2}$$

$$\sigma = \left[\frac{(\Delta U)^2}{T} \ \sum \left|\frac{ni^2}{\Delta t}\right| \ - \ \left(\frac{U_T - V_O}{T}\right)^2\right]^{1/2}$$

σ = 2.38 ft/sec^2

σ = 2.38/3.28 =0.73 m/ sec^2

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The work was carried out at the college of Engineering. University of Mosul