Analysis of traffic inflow to a university campus in a developing country : A rescale range approach

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Abstract

All over the world, there is an increasing enrolment level for university admissions in view of the ever-increasing benefits of earning university degrees. Thus, the high population of students in many universities, coupled with a high number of vehicles has made traffic control a challenge to University traffic managers. In this paper, the method of Rescale Range Analysis (RRA) was used to estimate the Hurst Exponent Value (HEV) for the traffic inflow through the main entrance gate of a university as a control measure. Data from a university in the developing countries was collected and analysed. The number of vehicles that entered consecutively per five minutes was observed between 07:00 and 19:00 over a 144 count and 17 independent cases constructed between adjacent cases. Rescale Range Algorithm platform is then used for the data, and coded in FORTRAN Language. With a case made up of 128 consecutive five-minute dependent traffic inflow records, a total of 3348 vehicles entered the university community within the studied period while the average number of vehicles inflow per hour was 279. Average number of vehicles that entered per five minutes was 24. No vehicle entered between 13:25 and 13:30. For all cases, the estimated HEV range between 0.5742 and 0.6955. The computed average HEV was 0.6303, the coefficient of fitness (R^2) for all cases range between 0.9552 and 0.9787, while the computed average value was 0.9680. The HEV greater than 0.5 estimated for all cases is an indication of positive correlation called Persistent. It expresses the fact that there are extended periods in which the traffic inflow to the university community deviated from the long term mean. This information is useful for vehicle garage design. For reliable estimates of the average HEV for design purposes, the study period should be extended to a whole week or an academic session.

Key Words: Traffic flow, car park, developing country, university, Rescale Range Analysis, Hurst Exponent Value

1. Introduction

In many countries of the world, there is an increasing level of enrolment for university education both at the undergraduate and postgraduate level. In developing countries such as Nigeria, the population explosion has aided this heightened demand for education since high qualifications have the potential for earning high level of income for the holders. In the university system, a common observation relates to a high number of vehicle users among students, many of which are from wealthy backgrounds. Thus, traffic congestion as a result of indiscriminate packing is commonly observed on campuses. This results in substantial loss of man-hours and exposure to accidents and risks by various stakeholders in the university. There is therefore the need for a scientific approach to control this undesirable problem. An approach in solving this problem is the proper design of car parks on campuses based on scientific information. This would prevent unauthorized parking of vehicles along the main roads of the university.

Since the problem solved in this paper falls under traffic flow, a number of related studies are investigated. Stewart (2007) examines and compares link-based tolling solutions to achieve both the SSO (where Total Perceived network Travel Cost (TPNTC) is minimized) and true SO (where Total Network Travel Cost is minimized. Meng et al. (2007) proposed a single-lane cellular automation model to simulate mixed traffic with motorcycles. Some density flow relations and the "lane-changing" behaviour of motorcycles were investigated. Gao et al. (2007) constructed an evolution network in the evolution process of traffic flow. The influence of traffic dynamics on the structural properties of the evolution network, and measure of probability distributions and scaling properties of the network were studied. The objective of this study is to use traffic flow information on campuses in predicting the number of vehicles that would be required at car parks (Tang et al., 2007). The scientific approach of Rescale Range Analysis (RRA) is utilized to estimate the Hurst Exponent Value (HEV) for the traffic inflow through the entrance of a university gate (Feder, 1988). In particular, data from the University of Ibadan, Nigeria was used with a focus on traffic inflow on a particular day (Monday) through the main entrance of the university.

This study is sectioned into introduction, method and materials, results and discussion, and conclusion. The introduction provides the motivation for the study, and a justification for using the approach proposed in this work based on identified gaps in the literature. The section on method and materials presents the framework in the modeling based on Rescale Range Analysis and the Hurst Exponent Value. The third section, results and discussion, presents the results, which were analysed with the aid of

FORTRAN programme that was imported into Microsoft Excel worksheet. The fourth section provides concluding remarks on the study.

2. Method and Materials

The method used to analyze the materials of this study is called Rescale Range. For a total period of twelve hours (12) the number of vehicles that came into the University Community through the main entrance gate was recorded in five (5) minutes piece meal. The observation and recording started on Monday at 07:00 prompt and ended the same date at 19:00 Nigerian time. The recorded data was transformed into seventeen independent cases of 128-data length (continuous in time) using time lag of five minutes reference to previous case. The data for each case was analyzed using the Rescale Range Algorithm coded in FORTRAN Language.

Mathematical model

The mathematical model used for this study is:

$$\frac{R}{S} \alpha T^{H} \qquad (1)$$

Rewrite equation (1) as follow:

$\frac{R}{S} = K T^{H}$ .Take logarithm of the two sides of this equation gives

$$Log(\frac{R}{S}) = Log(K) + H\, Log(T) \qquad (2)$$

Equation (2) is a straight line equation on a log-log graph with slope of the line being the Hurst exponent value (H)

Where R = Range (Maximum value –Minimum Value); S = Standard deviation; T = Study data Length (Minimum allowed in this study was four (4)); and H = Hurst exponent.

Interpretation of Hurst Exponent

(1) $H = \frac{1}{2}$; is the Hurst exponent value for uncorrelated time series data as in Random Walk.

(2) $H > \frac{1}{2}$; are the Hurst exponent value for positively correlated time series data (Persistence)

(3) $H < \frac{1}{2}$; are the Hurst exponent value for negatively correlated series data (Ant-Persistence)

Thus based on these interpretation any time series with Hurst exponent value $(H > 0)$ is doom to be positively persistent.

3. Results and Discussion

The results of this study are presented in table and graphical (prepared using Microsoft Excel) form as follow.

Table 1: Number of Vehicles Recorded Per Five (5) Minutes during the Studied Period

Period	Number of Vehicles Recorded Per Five (5) Minutes												Total Vehicles Recorded Per Hour
07:00-08:00	51	33	48	37	27	45	22	26	37	27	20	33	406
08:00-09:00	23	28	20	29	16	23	21	17	20	22	16	22	257
09:00-10:00	21	29	28	19	29	22	28	25	20	18	28	23	290
10:00-11:00	17	19	21	17	20	16	18	16	29	26	19	31	249
11:00-12:00	30	13	26	24	38	29	25	31	28	25	34	38	341
12:00-13:00	39	36	21	32	21	36	22	32	29	29	30	17	344
13:00-14:00	28	25	28	25	25	0	27	28	15	20	12	18	251
14:00-15:00	19	16	19	37	28	18	23	18	27	5	17	23	250
15:00-16:00	24	13	22	21	23	23	24	20	16	18	16	13	233
16:00-17:00	31	26	16	18	16	26	27	24	15	10	26	18	253
17:00-18:00	9	12	10	18	14	16	19	22	26	15	22	24	207
18:00-19:00	14	18	13	26	28	16	26	24	28	20	26	28	267
Total number of vehicles that entered through the University main entrance gate in 12hours													3348
Average Number of Vehicles per hour that entered through the University main entrance gate													279
Average Number of Vehicles per five minutes that entered through the University main entrance gate													24

Referring to Table 1 above it is found that the total number of vehicles that came into the University Community through the main entrance gate during the studied period was 3348 while the average traffic inflow per hour was 279. No vehicle came in between 13:25 and 13:30.

Table 2: Data length, Average Computed Rescale Range, Logarithm of Data Length and Logarithm of Average Computed Rescale Range for Case1

Data Length	Average Computed Rescale Range	Logarithm of Data Length	Logarithm of Average Computed Rescale Range
4	3.91078	1.38629	1.36374
8	5.79975	2.07944	1.75781
16	10.06981	2.77259	2.30954
32	15.64434	3.46574	2.75011
64	24.69409	4.15888	3.20656
128	27.20092	4.85203	3.30325

Using the data in table 2 above the graph in figure 1 below can be generated.

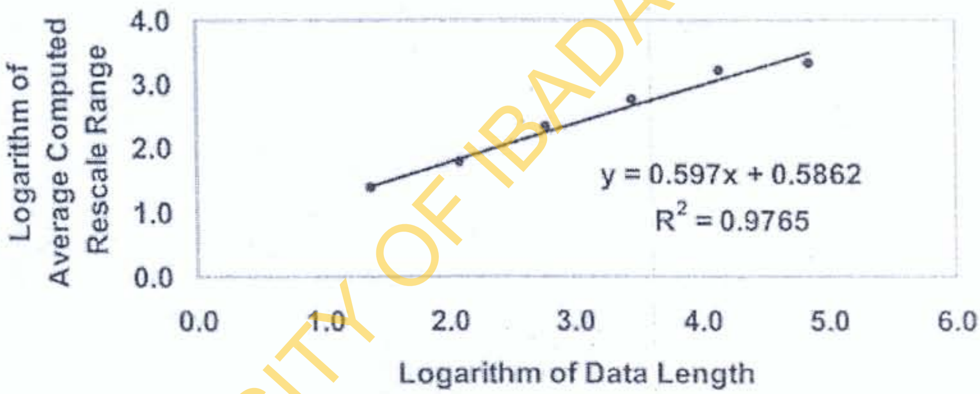

Figure 1 : Logarithm of Data Length Versus Logarithm of Average Computed Rescale Rang. (Case 1)

Referring to figure 1 the Hurst exponent value (H) for Case 1 is 0.597 indicating persistence.

Table 3: Data length, Average Computed Rescale Range, Logarithm of Data Length and Logarithm of Average Computed Rescale Range for Case16

Data Length	Average Computed Rescale Range	Logarithm of Data Length	Logarithm of Average Computed Rescale Range
4	4.31472	1.38629	1.46203
8	5.77868	2.07944	1.75418
16	8.56734	2.77259	2.14796
32	14.99468	3.46574	2.70770
64	27.91928	4.15888	3.32932
128	27.63277	4.85203	3.31900

Using the data in table 3 above the graph in figure 2 below can be generated.

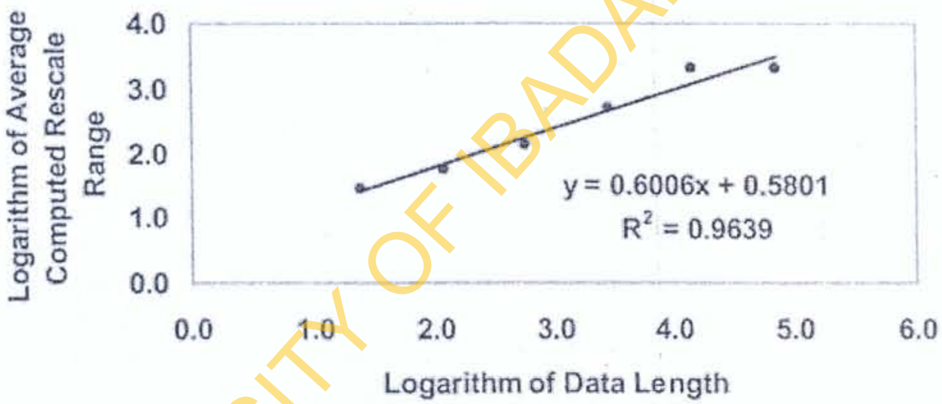

Figure 2 : Logarithm of Data Length Versus Logarithm of Average Computed Rescale Rang.

Referring to Figure 2 the Hurst Exponent value (H) for Case 16 is 0.6006 indicating persistence.

The remaining fifteen (15) cases (i.e. cases 2 to 15 and 17) were similarly analyzed to enable their Hurst exponent value estimate. The results obtained for all the cases are indicated in Table 4.

Table 4: Hurst Exponent Values for the seventeen Studied Cases

Case Number	Case Period	Hurst Value	R^2
1	07:00 to 17:40	0.5970	0.9765
2	07:05 to 17:45	0.6419	0.9762
3	07:10 to 17:50	0.6028	0.9774
4	07:15 to 17:55	0.5742	0.9787
5	07:20 to 18:00	0.6085	0.9733
6	07:25 to 18:05	0.6673	0.9732
7	07:30 to 18:10	0.6165	0.9664
8	07:35 to 18:15	0.5899	0.9629
9	07:40 to 18:20	0.6443	0.9666
10	07:45 to 18:25	0.6861	0.9646
11	07:50 to 18:30	0.6448	0.9630
12	07:55 to 18:35	0.6079	0.9552
13	08:00 to 18:40	0.6955	0.9589
14	08:05 to 18:45	0.6455	0.9584
15	08:10 to 18:50	0.6457	0.9683
16	08:15 to 18:55	0.6006	0.9639
17	08:20 to 19:00	0.6471	0.9718
Average Values		0.6303	0.9680

Referring to table 4 the Hurst value for all studied cases range between 0.5742 and 0.6955 while the coefficient of fitness (R^2) range between 0.9552 and 0.9787. The average Hurst value was found to be 0.6303. For all cases the Hurst value are greater than 0.5 indicating that the traffic inflow to the University Community during the studied period is persistent. It signifies the fact that there are extended periods in which the traffic inflow to the University Community deviated from the long term mean.

4. Conclusions

This study shows that traffic inflow to the University of Ibadan (Nigeria) on the day studied was positively correlated. This amount to a signpost telling that there are extended periods in which the traffic inflow to the university Community deviated from the long term mean and it is very useful Vehicle garage design information. It is recommended that for a reliable estimate of the average Hurst exponent value for design purposes the study period be extended to cover all days of the week if not all days of the University academic session. This will ensures more of five minutes dependent traffic inflow record, longer record for cases, more cases and ultimately a robust and reliable average Hurst exponent value.

5. References

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