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Night-Time Rainfall Effect on Road Service and Travel Time Loss: A Case Study of Roadway without Light

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Abstract

On roads without lights, the effect of night time rainfall on the functional quality of service is investigated in this paper. Functional level or quality of service (FQS) is taken as a qualitative measure of the operating conditions of a roadway where travel time and travel speed are used as key performance indicators. Travel time is used as proxy for road service users' quality perception and travel speed used as a proxy for road service provider's perception of service quality. Travel time in conjunction with travel speed and traffic flow were used to develop a novel six-class functional quality of service criteria table where Class A is the best and Class F is the worst. 24hr continuous traffic volume, vehicle speed, vehicle type and rainfall intensity data were collected for eight weeks at four selected 2-lane interstate roadways without light in Nigeria. Results show that an average travel time increase and corresponding travel speed decrease under light, moderate and heavy rainfall. Heavy rainfall caused the highest travel time increase of 9%. Whilst moderate rainfall accounted for 6% increase in travel time and light rainfall accounted for 4% travel time increase, FQS dropped from Class B to Class C during night rainfall on roadways without light. The paper concluded that rainfall has negative effect on the functional quality of service. The findings could be used in a variety of ways in traffic management to predict travel time under rainy conditions and prescribe speed limits accordingly.

Keywords: Night-time, rainfall, level of service, travel time, speed, traffic flow

1. Introduction

Road pavements are intended to sustain structural vehicular load as well as functional traffic flow over time. It can be argued that structural as well as functional quality of service are arguable the key performance indicators. Functional level or quality of service (FQS) is a measurement of overall traffic performance of service. Over the years, measuring quality of service has become a critical area of interest to highway practitioners for design and management purposes. Highway Capacity Manual 2010 level of service (LOS) is often used to assess the quality of service. LOS is an effective measure of a travel speed no doubt, but it is one dimensional. Moreover, HCM-LOS is quiet on estimation of criteria table parameters. In this paper, functional quality of service is presented a measure based on service perception of road users and providers.

List of notation

T	Travel time over roadway length
t_f	Travel time at free-flow speed
x	degree of saturation $(\frac{v}{Q})$
v	demand traffic volume,
Q	traffic capacity
ρ	ratio of free-flow to speed at capacity
β	abrupt drop of curve from the free-flow speed
q	Flow
u	speed
u_Q	speed at capacity
k	density
u_f	free-flow speed
k_Q	density at capacity

The criteria table parameter estimation methods are presented and discussed. Travel time is used as proxy for road users' service perception and travel speed retained as proxy for road providers' perception of service. There is no previous study on the effect of night time rainfall on functional quality of service (FQS) on roads without lights. Many studies have shown that speed reduction, capacity loss, travel time increase amongst others would result from driving under rainy conditions (Chung et al., 2006; Mashros and Ben-Edigbe, 2013; Ben-Edigbe, 2014; Wang and Luo, 2016; Zhang et al., 2017). Xu et al. (2013) considered rainfall occurrences as a source of uncertainty capable of affecting traffic regarding safety and operation. According to Alhassan and Ben-Edigbe, (2011), rainy conditions are amongst the causes of traffic instabilities and other traffic-related problems on highways. The studies were carried out on road traffic performances under daylight and rainy conditions or night time on roads with light. Road lights are important safety feature for drivers where visibility is essential. Driving in the rain at night poses seriously challenges. It is made even more difficult by the consequence of specular reflection and the absence of road light. Often, there is no legal requirement to provide street lighting in high income countries, yet the provision of road lights is near total. Lights are not switched off on busy roadways with high traffic volumes. In Nigeria where the study was carried out, nearly all interstate highways are without lights even though dependence on transportation by road is near total. The country has one of the lowest net electricity generation per capita rates in the world and has lurched from one power crisis to another one without end in sight, in spite of an abundant supply of oil, gas, hydro and solar resource. In this paper the effect of night time rainfall on the functional quality of service of roads without lights is investigated.

2. Literature

Functional quality of service (FQS) is a qualitative measure of the operating conditions of a roadway based on travel time and speed among others. According to Florida State Department of Transportation (FDoT) Quality and Level of Service Handbook (2013), quality of service is a traveler-based perception of how well a service or facility is operating. Consequently, quality of service cannot be used interchangeably with level of service because level of service is a road provider-based perception of how well a service or facility is operating. If quality of service is a traveler-based perception, then travel time can be used as proxy. Travel time is taken as a function of free flow speed and volume/capacity ratio whereas speed is a function of travel flow and roadway density. It can be calculated using equation 1 according to US Bureau of Public Roads (US-BPR

$$T = t_f\left[1+\rho(x)^{\beta}\right] = t_f\left[1+\rho\left(\frac{v}{q}\right)^{\beta}\right] \qquad 1$$

The parameter Q defined as capacity is used to measure road performance under its prevailing conditions. For the values of ρ and β, BPR (1965) recommended 0.15 and 4 respectively traffic volume equals traffic capacity (v/q). However, due to underestimation of speed, Dowling and Skabardonis (1993) suggested ρ = 0.2 and β = 10 for scenarios where volume capacity ratio is less than 0.9 because the high value of β would make speed unresponsive to x as it tends to 1. So, there is no need to formulate a new travel time model. Traffic capacity is a key parameter in equation 1, in estimating the parameter Q, the flow-density relationship is considered by Ben-Edigbe and Ferguson (2005). According to Ben-Edigbe and Ferguson (2005). Traffic capacity can be determined from the flow-density relationship expressed as equation 2

$$q = -ak^2 + bk - c \qquad 2$$

Estimation of road capacity has received considerable attention in past studies. Capacity estimation using empirical data as reported by Minderhoud et al. (1997) could be by the following methods viz headways, estimation using traffic flow (selected maxima method, expected extreme value and bi-modal distribution method), use of traffic flow and speed (Product Limit method) and use of traffic flow, speed and density (fundamental diagram). According to them, the choice of each method depends on various conditions which include location choice for observation, the required observation period, type of data to be collected, lane or carriageway and traffic state. Headway and fundamental diagrams estimation method are used for off-peak traffic state. Since the interest of this study is at night-time which is an off-peak traffic state, the fundamental diagram method is adopted for capacity estimation. If flow, q is differentiated w.r.t to density, k in equation 2, then

$$\frac{\partial q}{\partial k} = -2ak + b = 0 \rightarrow k = \frac{b}{2a} \qquad 3$$

$$\frac{\partial^2 q}{\partial k^2} = -2a = 0 \rightarrow a = 0 \qquad 4$$

In order to estimate capacity, q, insert equation 3 into equation 2;

$$q = -a\left(\frac{b}{2a}\right)^2 + b\left(\frac{b}{2a}\right) - c \qquad 5$$

Speed at capacity,

$$u_Q = \frac{-a\left(\frac{b}{2a}\right)^2 + b\left(\frac{b}{2a}\right) - c}{\left(\frac{b}{2a}\right) + \left(\frac{b}{2a}\right) - \left(\frac{b}{2a}\right)} \rightarrow u_Q = -a\left(\frac{b}{2a}\right) + b \qquad 6$$

Note that in eqn. 4, a = 0 only when speed is at k_j because a = $\frac{\partial q}{\partial k}$

In order to estimate travel time, insert equation 5 into equation 1 so that;

$$T = t_f\left[1+\rho\left(\frac{v}{Q}\right)^{\beta}\right] \Rightarrow T = t_f\left[1+\rho\left(\frac{v}{-a\left(\left[\frac{b}{2a}\right]^2\right)+b\frac{b}{2a}-c}\right)^{\beta}\right] \qquad 7$$

Where: T = predicted time over roadway length; t_f = travel time at free-flow speed

x = degree of saturation ($\frac{v}{q}$); v = demand traffic volume, q = capacity

ρ = ratio of free-flow to speed at capacity

β = abrupt drop of curve from the free-flow speed

q = flow (veh/hr), u = mean speed (km/hr), k = density (veh/km)

u = speed, u_f = free-flow speed and k_j = jam density

According to Ben-Edigbe and Ferguson (2005), a linear relationship between speed and density given as;

$$u = u_f - \frac{u_f}{k_j}k \qquad 8$$

Travel speed,

$$u = \frac{d}{T};\ u = d^{-1}\left\{t_f\left[1+\rho\left(\frac{v}{-a\left(\left[\frac{b}{2a}\right]^2\right)+b\frac{b}{2a}-c}\right)^{\beta}\right]\right\} \qquad 9$$

Where; u denotes travel speed; d denotes distance; and T denotes travel time

Equation 7 is suitable for determining travel time for rainy and dry conditions during daylight and at night-time periods, provided traffic volume is converted to flow with modified passenger car equivalent values. Mashros et al (2012 & 20143) suggested that using travel time together with speed and flow measures the quality of road service delivery. Shi et al (2013) examined rainfall effect on expressway travel time in Shanghai Pudong and identified four levels of rainfall (slight, moderate, heavy and very heavy). According to the study, rainfall especially heavy rain has a significant effect on travel time.

In many studies, quality of service is often mentioned as service measures of travel speed, travel time, traffic interruptions, manoeuvrability freedom, comfort and convenience without clarity. Most studies rely on speed as a measure of effectiveness. Speed as a service measure is used by road producers to evaluate the level of service whereas the road users are often more concerned with travel time not vehicle speed as a measure of effectiveness. Consequently, it may be proper to state that user's perception of functional quality of service delivery is time-based, hence the adoption of travel time as a proxy for road users perception of functional quality of service. Ben-Edigbe et al. (2014) stated that the concept of road service quality is a function of travel time, speed and volume-capacity ratio. In this paper, FQS is presented as a bi-perception assessment concept driven by travel time and speed. Travel time in conjunction with speed and flow were used to construct the novel functional quality service (FQS) criteria table illustrated in figure 1.

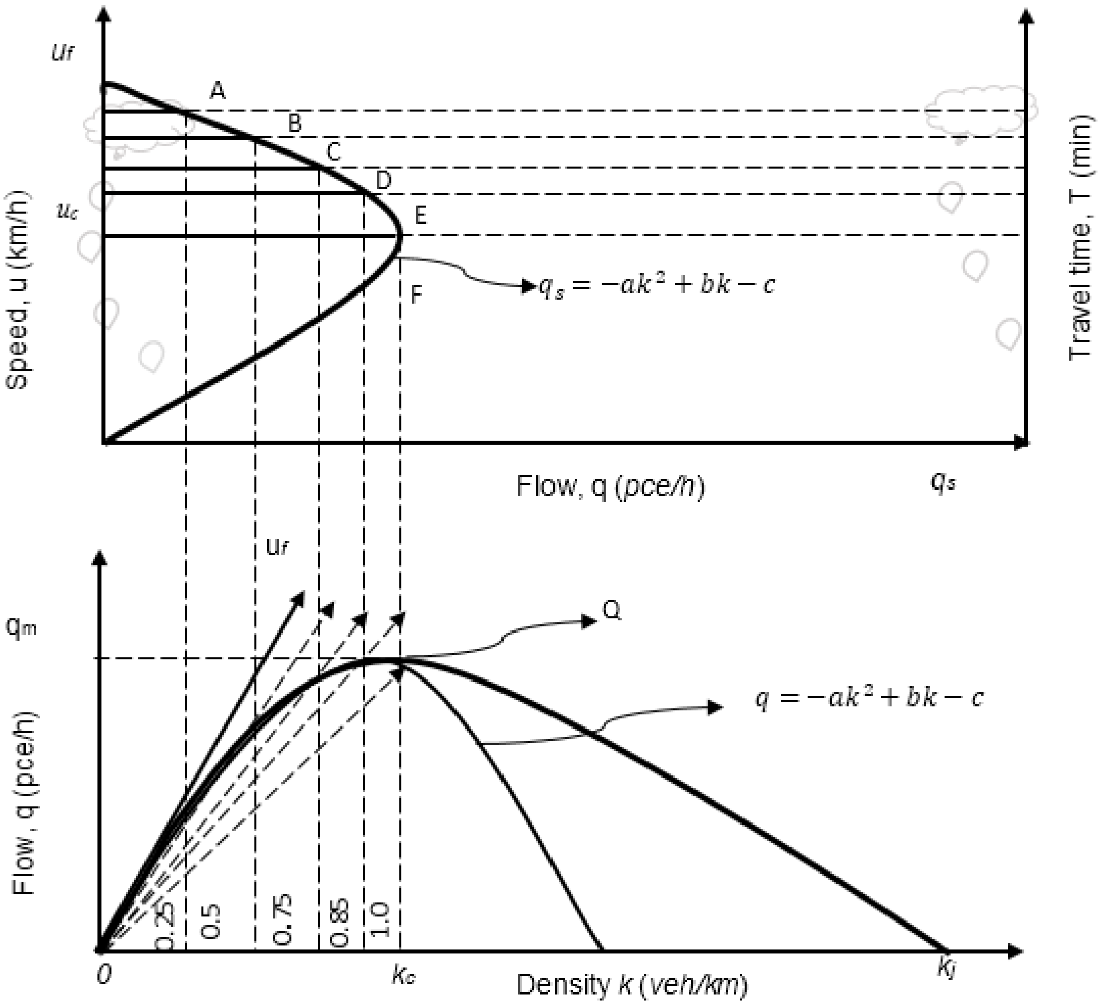

Figure 1: Hypothetical Functional Quality of Service Curves

The first step is to determine flow/density asymmetrical curve, then partition the curve into two sections (uncongested and congested). One advantage of using flow-density relationship as against speed-flow relationship used by HCM is that all the three basic traffic stream parameters are represented by the curve. The second step is to partition the uncongested section of the flow density curve into four equal strips. There are no basic standards for the equal strip partitioning, however, it is pragmatic to use even ratios such as ≤ 0.25, ≤ 0.5, ≤ 0.75, and 1.0. Thereafter, insert a threshold ratio of 0.85 as appropriate. In many studies, 0.85 is regarded as the performance threshold as traffic flow approaches capacity. It had been used by Highway Capacity Manual (2010), Transport Research Board (TRB, 1998) and other previous studies such as Hou et al. (2012) and Mashros et al. (2013) and in this paper. Now there are five strips in the uncongested section namely; Class A, B, C, D and E. Note that Class D is the threshold, Class E is the capacity and Class F is the congestion section of the asymmetrical curve. The free flow speed is contained in the model equation 2 term *bk* and also used to compute the travel time for Class A. For Class D, Equation 6 is used to compute the speed at capacity and equation 7 used to compute the travel time at capacity where $^{V}/_{Q} = 1$. In sum, it is useful to evaluate travel time and travel speed so that the perceptions of service providers and users are taken on board when assessing functional quality of service (FQS).

3. DATA COLLECTION

Traffic and rainfall data were collected continuously for eight weeks at four selected two-lane highway without road light in Nigeria. Proximity to rain gauge catchment range is sacrosanct to the study. Selected sites are straight with flat terrain with functional drainage system and free from pavement distress. Rainfall data were obtained using rain gauge with data-logger. The data-logger records rainfall events at 1-minute interval continuously. Using a 5-min interval, the obtained data was separated into daylight and night-time data. The rainfall precipitation amount was converted into intensity and separated into light ($i < 2.5$mm/hr), moderate ($2.5 \leq i < 10$ mm/hr) and heavy ($10 \leq i < 50$ mm/hr) and very heavy ($i > 50$mm/hr) rainfall in line with World Meteorological Organisation classification. Very heavy rainfall was not considered in the study due to aquaplaning and drag force. Traffic data were collected with an Automatic traffic counter (ATC) as shown below in figure 2. It is important that the segment length (L) be greater than sight distance (SSD) in order to increase the probability of unbiased vehicle data collection. As shown in figure 2, two sensor tubes set at one meter apart were attached to the ATC counting machine. Vehicle information captured by the ATC include the following speed, volume, weight, headway, gap, type of vehicle, date and time of vehicle hit. Note that RG denotes rain gauge. It is important that the survey site must lie wholly within the catchment area of the rain gauge.

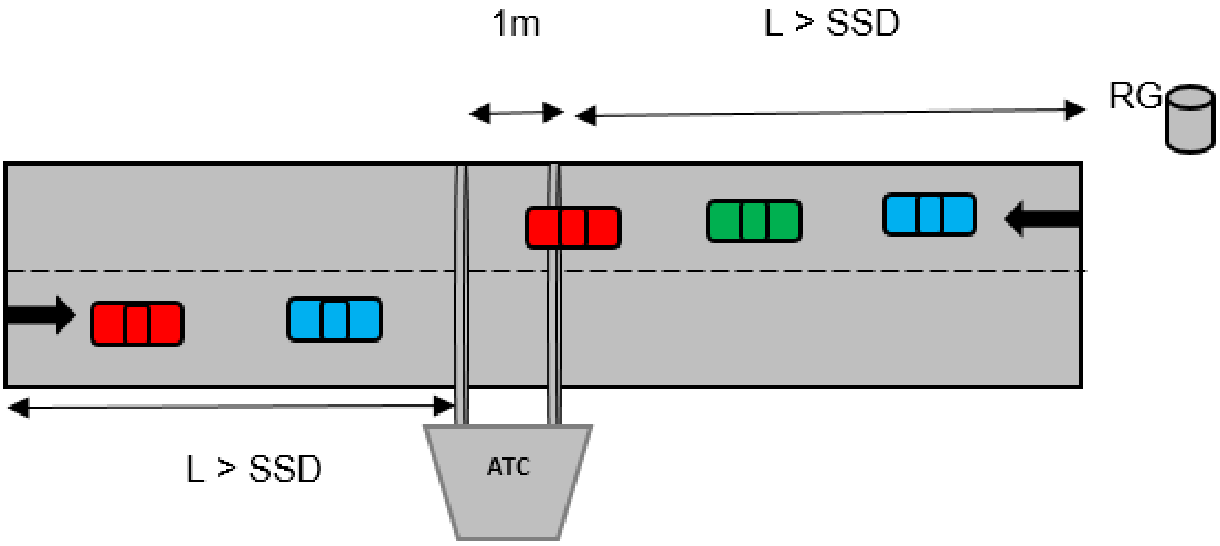

Figure 2 Typical survey site layout

4. RESULTS AND DISCUSSION

Road lighting provides a number of important benefits. It can be used to promote security **in** urban areas and to increase the quality of life by artificially extending the hours **in** which it is light so that activity can take place. Driving on roads without lights is very challenging; during the rainy season it is dangerous and unsafe with consequences for functional quality of service. It's a familiar sight to see motorists disembark to push crippled vehicles in the rain. Note that typical daylight period is between 6am and 6.30pm while the night-time is between 6.30pm and 6am. Typical 24hr traffic flow activities on roads without light in Nigeria are time dependent. Traffic flow activities pick up around 6 A.M and gradually slow down around 6 P.M. Traffic flow within the period of 7.30 pm - 11 pm were considered for night time. Traffic flows beyond 11 pm are usually low (below 100veh/h) and characterised by high headway and heavy good vehicles. Stepwise analytical method was adopted for clarity and procedural ease.

Step 1: Convert traffic volume to traffic flow using modified passenger car values. Separate traffic data into peak and off peak. Typical traffic stream data are shown below in table 1. Traffic flows with their corresponding speed values were used to estimate densities thus suggesting that changes were the result of speed.

Table 1: Typical Traffic Stream Data

Rainfall Intensity at Night on Roadway without light											
Dry			Light Rain i≤2.5mm/h			Moderate Rain i≤10mm/h			Heavy Rain i≤50mm/h		
u	q	k	u	q	k	u	q	k	u	q	k
70	210	3.0	49	195	4.0	57	240	4.2	62	255	4.1
81	300	3.7	65	375	5.8	50	143	2.9	52	263	5.0
80	300	3.8	45	240	5.4	62	210	3.4	65	165	2.5
70	195	2.8	65	165	2.5	70	240	3.4	47	60	1.3
87	180	2.1	68	248	3.7	65	180	2.8	74	135	1.8
62	195	3.1	73	210	2.9	76	150	2.0	49	233	4.7
85	450	5.3	61	173	2.8	63	90	1.4	56	180	3.2
75	323	4.3	60	480	8.0	50	135	2.7	53	158	3.0
66	195	3.0	70	203	2.9	64	150	2.3	40	90	2.3
60	293	4.9	68	383	5.6	60	150	2.5	82	188	2.3
75	248	3.3	52	120	2.3	75	150	2.0	55	195	3.5
81	248	3.1	57	300	5.3	55	120	2.2	62	225	3.6

Note that in the table below, *u* denotes speed-km/h, *q* denotes flow-veh/h, *k* denotes density-veh/km.

Step 2: Use the daylight peak traffic data to construct FQS criteria table. Determine the flow-density relationship of the peak traffic performance under daylight and dry weather conditions. Test the ensuring model equation for statistical fitness. For example, Model equation 10, the coefficient of correlation R^2 was greater than 0.5 which signifies that the variables are significant. F-test values were greater than 2 suggesting that the equation did not happen by chance.

$$q = -1.114k^2 + 85.518k - 0.438 \quad R^2 = 0.94 \qquad 10$$

From model equation 10, free flow speed is about 86km/h (85.518k)

Differentiating equation 10, $\frac{dq}{dk} = -2.228k + 85.8 = 0$

Density at capacity, $k_Q = 38veh/km$

Traffic capacity; $Q = -1.114 * (38)^2 + 85.52 * (38) - 0.438 \approx 1650$pce/h

The speed at capacity; $u_Q = \frac{Q}{k_c} = \frac{1650}{38} = 43km/h$

Step 3: .Create FQS flow density curve and divided into six classes; Class A to Class F as shown below in figure 5 (note that the slope is speed). Class A is the highest and F is the lowest. In the previous step, capacity has been determined as 1650 vehicles per hour, approximated as 1700veh/h and classified as Class E. Class E is the capacity class where volume/capacity ratio is 100%. Using equation 2, for $^{V}/_{Q} = 1$; the ratio of free-flow to speed at capacity (ρ) is 0.15 and the abrupt drop of curve from the free-flow speed (β) is 4}. Speed at capacity ≈ 40km/h, hence the equivalent time is 1.5min 23s, hence Class E Travel time, T = 1.5 * 1.15 = 1.73min. Class D is the threshold class where volume/capacity ratio is 85%, hence 0.85 *x* 1700 ≈1500 veh/h. Class C (75% of 1700), Class B (50% of 1700), and Class A (25% of 1700). Derive travel time for Class A from equation 10 where $U_f \approx 85$km/h and the equivalent time $t_f = 42$s (0.7min); hence Class A travel time, T = 0.7 * 1.2 = 0.84min.

Note that Class A to D; $^{V}/_{Q} < 0.9$ hence t_f *x* 1.2. Estimated criteria table for functional quality of service under prevailing conditions is shown below in table 2.

Table 2: Functional Service Quality (FQS) Novel Criteria Table

CLASS	T (min)	*u* (km/h)	*q* (pce/h)	*k* (veh/km)	*h* (s)
A	T < 0.84	*u* > 85	*q* < 500	k < 6	h > 7.2
B	0.94	75	900	12	4.0
C	1.10	65	1300	20	2.8
D	1.30	55	1500	27	2.4
E	1.73	45	1700	40	2.1
F	*T* > 1.73	*u* < 40	*q* < 1700	*k* > 42	*h* < 2.1

T = travel time, *u* = speed (±10%), *q* = flow rate, *k* = density; *h*= headway

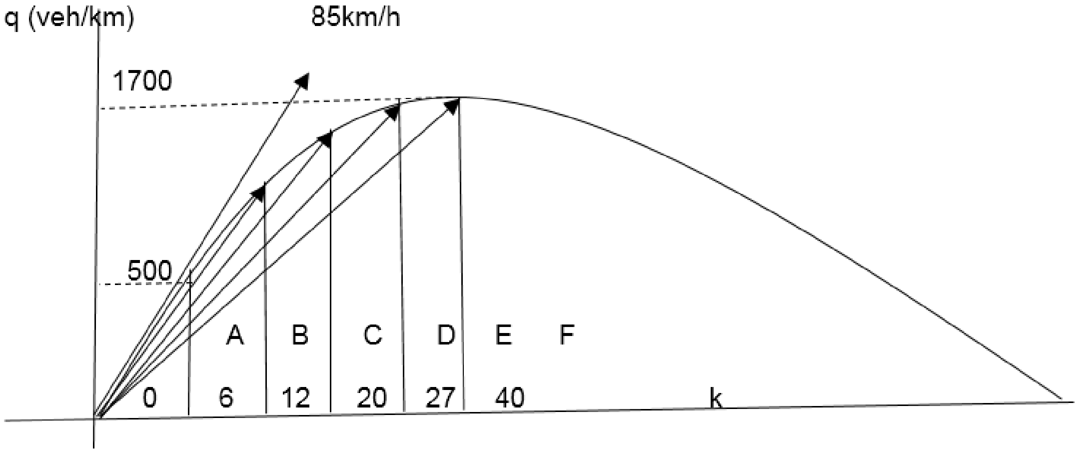

Figure 5. FQS flow/density curve

Step 4: Determine the flow-density relationship of prevailing condition as shown below in figure 6. Again test the model equations for statistically fitness. Determine traffic capacity, density and speed at capacity as illustrated in step 3. For example,

$$q_D = -1.0123k^2 + 69.764k - 0.9499 \quad R^2 = 0.9427 \qquad 11$$

From Equation 11, the free flow speed is approximately 70km/h (69.764k)

Equivalent time at free flow speed (t_f) is 0.85min

Travel time, T = 0.85 {1 + 0.2 $(0.9)^{10}$} = 0.91min.

Frome the criteria table 2, FQS is Class B. The results for all sites are shown in table 6.

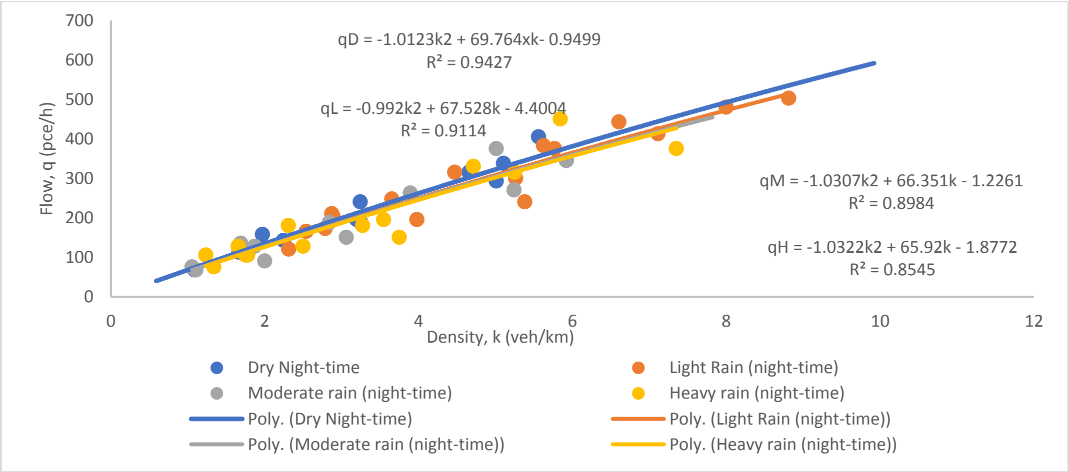

Figure 6: Typical Flow-density curves for prevailing conditions

Step 5: Comparative assessment of daylight and night time traffic performances under dry weather condition. Night time traffic performance sensitivity assessment is used to ascertain whether traffic flowrate on roadways without light will change relative to night time under dry weather conditions. As shown in table 2 under dry weather condition, average daylight free flow speed dropped from 85km/h to 70km/h at night time. Average travel time increased from 0.74min under daylight to 0.91min at night time. Average travel time increased by 21% speed decreased by 17% and the mean functional quality of service (FQS) dropped from Class A to Class B.

Step 6: Comparative assessment of dry night time and rainy night time traffic performances. Compute night time travel time and travel speed under rainy (light, moderate and heavy) conditions.

Average travel time under dry and night time conditions on roads without lights is 0.91min with corresponding average travel speed of 70km/h and FQS Class B. Whereas the average travel time under light rainfall is 0.95min (+4%) with corresponding travel speed of 67km/h (-4.3%) and FQS Class C. Average travel time under moderate rainfall is 0.97min (+6%) with corresponding average travel speed of 65km/h (-7.1%) and FQS Class C. Average travel time under heavy rainfall is 1min (+9%) with corresponding average travel speed of 64km/h (-9.2%) and FQS Class C. Generally, travel time increased by 4% during light rain, 6% during moderate rain and 9% during heavy rainfall. Note that in Table 3, LN is light rain; MR is moderate rain and HR is heavy rain.

Table 3: Night Time Functional Quality of Service on Roads without Light

Site	Weather	Model Equations	u_f (km/h)	t_f (min)	$\rho\ (0.9)^{\beta}$	1+col 6	T (min)	FQS
01	Dry D	$-1.1567k^2 + 88.387k - 2.28$	88	0.667	0.070	1.070	0.71	A
	Dry N	$-1.0123k^2 + 69.764k - 0.95$	70	0.850	0.070	1.070	0.91	B
	LR(N)	$-0.9920k^2 + 67.528k - 4.40$	67	0.883	0.070	1.070	0.94	C
	MR(N)	$-1.0307k^2 + 66.351k - 1.23$	66	0.900	0.070	1.070	0.96	C
	HR(N)	$-1.0322k^2 + 65.420k - 1.88$	65	0.917	0.070	1.070	0.98	C
02	Dry D	$-1.0526k^2 + 82.246k - 0.28$	82	0.717	0.070	1.070	0.77	A
	Dry N	$-0.9746k^2 + 66.169k - 2.67$	66	0.900	0.070	1.070	0.96	C
	LR(N)	$-0.9890k^2 + 63.380k - 1.18$	63	0.950	0.070	1.070	1.02	C
	MR(N)	$-0.9198k^2 + 60.616k - 0.33$	61	0.983	0.070	1.070	1.05	C
	HR(N)	$-1.0331k^2 + 62.095k - 1.74$	62	0.967	0.070	1.070	1.03	C
03	Dry D	$-1.0794k^2 + 83.034k - 0.47$	83	0.717	0.070	1.070	0.77	A
	Dry N	$-1.0240k^2 + 75.176k - 1.01$	75	0.783	0.070	1.070	0.84	B
	LR(N)	$-1.0993k^2 + 70.579k - 6.89$	70	0.850	0.070	1.070	0.91	B
	MR(N)	$-1.0886k^2 + 69.610k - 1.18$	69	0.867	0.070	1.070	0.93	B
	HR(N)	$-0.9699k^2 + 63.653k - 0.27$	64	0.933	0.070	1.070	1.00	C
04	Dry D	$-1.1140k^2 + 85.518k - 0.44$	86	0.683	0.070	1.070	0.73	A
	Dry N	$-0.9424k^2 + 69.924k - 0.58$	70	0.850	0.070	1.070	0.91	B
	LR(N)	$-0.9962k^2 + 69.160k - 2.34$	69	0.867	0.070	1.070	0.93	B
	MR(N)	$-1.0296k^2 + 66.537k - 4.64$	67	0.883	0.070	1.070	0.94	C
	HR(N)	$-1.0971k^2 + 67.539k - 6.49$	67	0.883	0.070	1.070	0.94	C

Note: N- night time; u_f- free flow speed ±10%; t_f- free flow time; ΔT- time differential; ρ=0.2; β =10

There is no previous rainfall impact study at night time on roads without lighting, however trend comparisons can be made with previous studies under rainy conditions. In previous study by Mashros et al (2012) under daylight conditions, travel time increase of 0.43, 0.54 and 0.74min per km were estimated for light, moderate and heavy rain respectively. In this study, carried out at night on roadways without light, travel time increase of 0.04, 0.07 and 0.09min per km were estimated for light, moderate and heavy rain respectively. Although the estimated travel time figures are different, nonetheless the trend is the same; travel time increase relative to rainfall intensity. In another study by Tsapakis et al (2013) carried out during daylight, average travel time increased by 0.1-2.1% for light, 1.5 - 3.8% for moderate and 4.0 - 6.0% for heavy rain. In this study, carried out at night on roadways without light, travel time increase of 4%, 6% and 9% were estimated for light, moderate and heavy rain respectively. Although the estimated travel time percentages are different, nonetheless the trend is the same; travel time increase relative rainfall intensity. Xu et al (2013) reported a reduction in operating efficiency and level of service due to rainfall on an urban road network in Guangzhou Haizhu, China. These studies were not carried out on roadways without light. Nevertheless, it suggested that the level of service will be reduced during rainfall. In this study, functional quality of service (FQS) reduction was caused by rainfall. In sum, driving at night on roads without light would result in lower travel speed and increased travel time. Based on the empirical findings in this paper, it is correct to say that night time rainfall on roadways without lights has effect on travel time and speed. The paper has also shown that night-time rainfall cannot on its own be called upon to account for functional quality of service reduction.

5. CONCLUSIONS

The absence of road lights provides night time driving with challenges in many ways, rainfall only exacerbate the problems. In this paper, the effect of night time rainfall on Functional Quality of Service (FQS) was investigated. Functional Quality of Service (FQS) was presented as a bi-perception concept driven by travel time and speed. Six classes A to F were identified. Travel time was used as proxy for road users and speed as proxy for road providers' perception of service quality. Heavy rainfall caused the highest travel time increase of 9%. Whilst moderate rainfall accounted for 6% increase in travel time and light rainfall accounted for 4% travel time increase, FQS dropped from Class B to Class C during night rainfall on roadways without light. The paper concluded that rainfall has negative effect on the functional quality of service. The findings could be used in a variety of ways in traffic management to predict travel time under rainy conditions and prescribe speed limits accordingly.

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