Characteristics of Driving Behavior According to Accumulative Task Loading Time of Intra-city Bus Driver

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Abstract: Most Intra-bus accidents are caused by changes of driver behavior in terms of carelessness of safety driving. And changes of driving behavior are closely related to driving time. Therefore this study focuses on analyzing a relationship between bus driver's accumulative task loading time and driving behavior. As a result, it is quite probable that the abnormal behavior was shown in 4, 5th driving time and potentially accidents occurred.

Keywords: Black box data, Driving behavior, Task loading time, Bus driver, Intra-city bus.

1. INTRODUCTION

According to Korea Research Institute of Transportation Industries, accident rate (num/year) related to intra-city bus reached 85% of all bus traffic accidents, which include the intra and inter bus in Korea, 2010. The causes about intra-city bus traffic accidents are crash stop, safety distance violation, negligence in keeping looking forward. These are related to human element and carelessness of safety driving by changing driving behavior. The changes of driving behavior are closely connected to driving time. The bus driver works 10 hours averagely and drives long time. It means the bus driver is overloaded with tasks. The long driving time (task loading time) leads to driver's abnormal behavior such as low concentration, driving while drowsy and becomes the causes of carelessness of safety driving. Furthermore, it can be latent casual factor to cause bus traffic accidents.

Although the driver behavior is very important to analyze the cause of traffic accident, however, a study related to a human element is less sufficient than elements of road environment and vehicles because of difficulty of collecting data and some technical reasons. Although these data is used in analysis or studies of accidents, there are just few studies that used the collected data about a human element. Also most studies related to driving time have been done in human physiology not behavior. Accordingly, this study analyzed a relationship between driver's abnormal behavior which can generate accidents and driving time (i.e. Accumulative task loading time)

2. LITERATURE REVIEW

Few investigations on bus-related accidents are made from the academic perspective. However bus traffic accidents have been studied steadily. Mohammad M. Hamed(1998) studied about mini-bus traffic accidents to gain the factors affecting accidents and severity. And Oh(2009), who studies using the black box data, developed critical value of commercial vehicles(bus) depending on type of risky driving which can improve drivers' safety driving

based on a Risky Driving Judgment Device. Also Oh calculates weight value depending on type of risky driving by experimenting for general drivers using a simulator which has program for judging risky driving in another study (2009).

Also there are some studies about a relationship between driving time and fatigability which is carried out to figure out the time when a driver's driving pattern changes. Kim(2002) studied change of fatigability by driving time through experiment using electrocardiogram(ECG) and electromyogram. The result of experiment is drivers need proper break time in driving over 1 hour depending on increasing of driving time. and ping-huang tine(2008) experimented to find driver's fatigability through simulation. They conclude driving time is limited to 80 minutes and drivers need to take break time in every 80 minutes.

Most of existing studies have researched based on physiology for establishing a relationship between driving time and accidents. And few studies of driving behavior are researched. Moreover most studies about the Black box data are used for judging hazard driving and there are few studies about driving time.

3. METHODOLOGY

3.1 Black Box Data

The black box data used in this study has driving information written by the black box in the bus vehicle. The black box data has 11 information, which is written per second, such as a day driving distance, accumulated driving distance, date, vehicle speed (km/h), RPM, sign of brake, position of vehicle (GPS x, y-coordinate), azimuth of GPS, acceleration (m/sec^2), and condition code of on-line.

3.2 MOE setting

Measure of effectiveness (MOE) should be set in advance. A speed, the acceleration, the RPM, and the difference of RPM are used as MOE for analyzing driver's behavior in this study.

1) Speed: The speed of something is the rate at which it moves or travels as moving distance per unit time. It means vehicle speed per second and unit measure is km/h. It is fundamental factor to show driver's feature.

2) Acceleration: The acceleration of a process or a change is the fact that it is getting faster and faster. It means difference between speed at t (time) and at t+1(time) written by the black box. And its unit measure is m/sec^2. It shows how many times a driver puts on the accelerator or the brakes.

3)RPM: RPM is used to indicate the speed of something by saying how many times per minute it will go round in a circle. It means RPM per second written by black box. It shows behavior about level of accelerator for acceleration.

4) Difference of RPM: It is changed quantity of RPM per unit time. It means difference between RPM at t (time) and at t+1(time) written by black box. It shows behavior about level of accelerator every a second.

3.3 Driving pattern

Every driver does not have the same feature during driving but each driver has different feature. For example there are some people who usually drive smoothly but the others drive

roughly. If both are evaluated by same measures, we can judge the driver who drives roughly has the abnormal driving behavior. Therefore the normal behavior is defined by each person than using same measures. And the normal behavior is usually the first time of driving per each person.

3.4 Classifying abnormal behavior

The abnormal driving behavior is defined as the driving behavior which leads to the traffic accidents by driving not in a normal way. It is behavior that driving carelessness generates by inexperienced driving, sleepiness, watch negligence, and so on.

However these are not separated definitely and don't have an accurate boundary or criteria. Some studies suggest critical value but each person is applied by each criterion because they have different features especially in case of bus drivers. Therefore abnormal condition is defined as over 85 percentile of MOE and under 15 percentile of MOE for applying individual criteria.

Table 1. Standard of abnormal condition

MOE	abnormal condition
Speed	$V_a \geq \mu_v + k\frac{\sigma}{\sqrt{n}}, V_a \leq \mu_v - k\frac{\sigma}{\sqrt{n}}$
Acceleration	$A_a \geq \mu_A + k\frac{\sigma}{\sqrt{n}}, A_a \leq \mu_A - k\frac{\sigma}{\sqrt{n}}$
RPM	$R_a \geq \mu_R + k\frac{\sigma}{\sqrt{n}}, R_a \leq \mu_R - k\frac{\sigma}{\sqrt{n}}$
difference of RPM	$DR_a \geq \mu_{DR} + k\frac{\sigma}{\sqrt{n}}, DR_a \leq \mu_{DR} - k\frac{\sigma}{\sqrt{n}}$

3.5 Analysis of variance

Analysis of variance (ANOVA) is used to analyze the difference means of groups. ANOVA is conducted for comparing the first driving time which is same as normal condition with the rest of driving time about Speed, Acceleration, RPM, difference of RPM. This is able to check whether they have certain patterns about driving behavior grouping the similar driving times.

3.6 Analysis of abnormal behavior

The longer the driving time continues the more the drivers do abnormal behavior generally. Although the driving condition is very good, a driver does abnormal behavior unconsciously, so the criterion of abnormal behavior is defined 15 and 85 percentile at this time. And we know abnormal behavior's ratio of n^{th} driving by this criteria. Even if driver would show abnormal behavior in this condition, however, the accident probability is very small by this condition. The accident probability is not absolute ratio of abnormal behavior, but relative ratio of abnormal behavior by continuous driving time. So these relative ratios are defined as the difference between ratio of abnormal behavior in good driving condition and ratio of the abnormal behavior by continuous driving time.

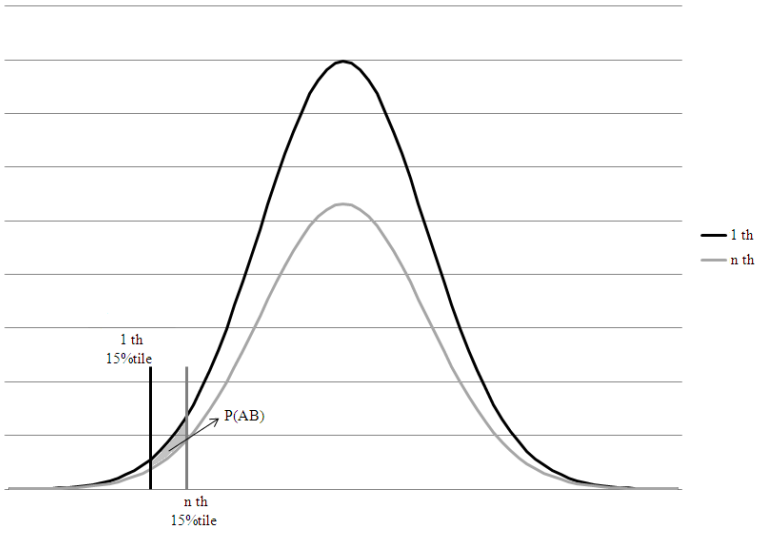

Figure 1. Relative ratio of abnormal behavior

$$P(AB) = R_{nx} - R_{sx} \quad (1)$$

Where,

$P(AB)$: Relative ratio of abnormal behavior

R_{nx} : Ratio of abnormal behavior by continuous driving time (n^{th})

R_{sx} : Ratio of abnormal behavior in good condition (1st)

x : x Percentile of good driving condition

A normal condition of bus driver is first driving time (working time). Each n^{th} ratio of abnormal behavior can be calculated using criteria of abnormal behavior drawn by first driving time. Abnormal behavior is analyzed by running time and continuous driving time through comparison of difference between ratio of frequency in 1^{st} driving time (normal behavior) and in n^{th} driving time (abnormal behavior).

4. APPLICATION AND RESULT

4.1 Data

Data used in this study is the black box data in March 2012. A running time of bus takes one and half hour with about distance of 20km. There are 17 vehicles and 34 drivers (2 drivers per 1 vehicle) to satisfy these condition. The brake time vary from 5 minutes to 1 hour after a running time. Some events are not regarded as bus driving time (speed is '0' over 10 minutes, total driving time is under 30 minutes, and so on), which were excluded. So each driver has 5 times per a day. And a standard of good condition is 1st running time. However the black box data doesn't show individual information (age, gender so on) and traffic condition.

Transformed data includes driving distance, accumulated driving distance, time, speed, and RPM. Acceleration and difference of RPM can be calculated by speed and RPM.

4.2 One-way ANOVA

One-way ANOVA with postmortem analysis, Duncan, is used for finding whether 1st driving behavior is similar to nth driving behavior.

Table 2 shows Duncan result of driver 1 & 2 in vehicle A. A running time of driver 1 is from division 1 to 5 and running time of driver 2 is from division 6 to 10. Two bus drivers drive 5 times each (totally about 5~7.5 hours). Division 1 is similar to division 2 in case of driver 1. Also division 1 is similar to division 3 and 4. In case of driver 2, division 6 is similar to 7 and to 8, 9. This means driving behavior of driver 1 and 2 are similar from division 1 to 4 and different from division 5. In other words the longer the driving time goes continuously the more the driving behavior changes after 5th driving.

However, not all drivers show this driving pattern. Just 5 of 34 drivers appear this driving pattern. And it is hard to interpret that they have certain driving pattern in continuous driving time because the traffic condition was not considered.

Table 2. Duncan result of driver 1 and 2

vehicle 1

Duncan a, b

Subset for alpha = 0.05

Division	N	1	2	3	4	5	6
9	2854	24.72					
10	2623		26.01				
8	2629		26.04				
6	2584		26.36	26.36			
7	2604			27.08			
5	2463				28.54		
3	2271					30.92	
4	2178					31.33	
1	2216					31.84	31.84
2	2108						32.45
Sig.		1.000	.518	.149	1.000	.084	.223

4.3 Result

17 vehicles and 34 bus drivers data of Black Box is used for analysis. First of all standard value which is 15 and 85 percentile was calculated in a normal condition, 1st running time. And the frequency of value by criteria in nth driver was calculated and it is shown as ratio (R_{s15}, R_{s85})

The result of driver 1 is shown in table 3. Table 3 shows that R_{s15} of speed in driver 1 increases gradually but R_{s85} decreases steadily. However there is no clear pattern on acceleration, RPM, and difference of RPM except for speed. Also other drivers except for driver 1 have patterns in different parts. And it is rare for drivers to show these clear patterns.

Table 3. Result of driver 1

driver1	no.	no. sample	15%tile	85%tile	by standard		$P(AB)$
					R_{s15}	R_{s85}	
	1	2216	12	49	-	-	-
	2	2108	11	52	0.163188	0.195446	0.055385
spd	3	2271	11	51	0.168648	0.179216	0.044615
	4	2178	10	50	0.182277	0.174931	0.053959
	5	2463	9	46	0.19732	0.119367	0.080661
	1	1743	-0.83333	0.833333	-	-	-
	2	1778	-1.11111	0.833333	0.169854	0.19685	0.041977
acc	3	1915	-0.83333	0.833333	0.169713	0.200522	0.045508
	4	1859	-1.11111	0.833333	0.179129	0.197418	0.051819
	5	2059	-0.83333	0.833333	0.15493	0.188441	0.020889
	1	3055	632	1171	-	-	-
	2	3314	631	1251	0.180447	0.201267	0.079259
RPM	3	3565	628	1187.1	0.223843	0.162693	0.084081
	4	3479	628	1286	0.212705	0.222765	0.133015
	5	3941	628	1162	0.222025	0.145902	0.075468
	1	2856	-56	55	-	-	-
	2	3081	-60	55	0.153846	0.151574	0.00395
diff.RPM	3	3327	-62	59	0.164412	0.159002	0.021944
	4	3255	-63.6	61.6	0.163134	0.162826	0.024489
	5	3639	-55	62	0.147843	0.163232	0.016439

However the difference of ratio in each value gets the highest value at 5th of speed (0.081), 4th of acceleration (0.052), 4th of RPM (0.133) and 4th of difference of RPM (0.024). There are differences from 2% to 13% compared with 1st driving time as standard driving time.

Table 4 shows ratio of nth driving time which has the highest relative ratio of the abnormal behavior ($P(AB)$).

The relative ratio is the highest at 5th in speed, at 4th in acceleration, at 5th in RPM, 5th difference of RPM. Relative ratio of abnormal behavior is totally the highest at 4, 5th considering 4 parts.

Table 4. Ratio of n th driving time which has the highest $P(AB)$

part	no.	freq.	ratio	%
spd.	2	7	0.2059	21
	3	6	0.1765	18
	4	10	0.2941	29
	5	11	0.3235	32
acc.	2	10	0.2941	29
	3	5	0.1471	15
	4	12	0.3529	35
	5	7	0.2059	21
RPM	2	5	0.1471	15
	3	9	0.2647	26
	4	9	0.2647	26
	5	11	0.3235	33
diff. RPM	2	7	0.2059	21
	3	6	0.1765	18
	4	10	0.2941	29
	5	21	0.6176	62

Both differences of acceleration and RPM which are relative value of speed and RPM show the driving behavior of individuals more fully than speed and RPM. The acceleration appears the driving behavior of individuals more properly because it varies depending on level of the brakes and accelerator. And the difference of RPM shows level of accelerator. The difference of RPM which just includes behavior of accelerator is more accurate measure than the acceleration because the acceleration was considered by mixing acceleration and deceleration. Since major cause of accident at the bus stop is a bus's quick start when it departs, the longer the driving time goes continuously the more frequent abnormal behavior is generated. In other words, it means potential probability of accident gets higher. In conclusion, abnormal behavior occurs at 4, 5th driving time and potential probability of accident is the highest at the time.

5. CONCLUSION

Black Box data is used to find the relationship between the driving time and the abnormal behavior. Therefore one-way ANOVA with postmortem analysis, Duncan, is carried out for finding driving pattern. As a result 5 of 34 drivers' show a regular pattern but there is no certain pattern of the driving behavior depending on the driving time in general.

The ratio of abnormal behavior at nth driving time compared to 1st is higher at 4, 5th than the others for most drivers. It is quite probable to appear higher ratio of the abnormal behavior

at 4, 5th. It means the traffic accidents would be generated potentially at 4, 5th.

However it is hard to define abnormal behavior just by using speed, acceleration, RPM, and difference of RPM because they can't consider traffic condition during driving. The traffic condition is considered for finding the relationship between abnormal behavior and driving time more clearly. If intra-bus drivers are classified by gender or age, and data is aggregated as groups with same feature, the result will be more accurate and reliable.

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