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Analysis of vehicle horn use and factors at intersections in an urban area of Taiwan

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ABSTRACT

In urban areas in many countries, noise pollution is generated by the frequent use of car and motorcycle horns. The final goal of the present study is to clarify the causes of horn use and to propose a transportation system to suppress horn use. To this end, we have investigated relationships between horn use and factors such as driver awareness, behavior, and vehicular environment. Our previous study investigated causal relationships between horn use and the vehicular environment in Taiwan, and found that horn use was more frequent when gridlock occurred at intersections. The present study analyzed details of gridlock situations at three intersections in Taipei during which vehicle horns were used. We found many cases where honking began after vehicles entered the intersection to turn left during the green-light phase. In particular, drivers often used their horns when they had to wait for more than 4 seconds for the vehicles in front of them to start moving after a green light allowed left turns. Logistic regression analysis revealed that the probability of a driver using a vehicle horn was significantly affected by the duration between the signal turning green and the vehicle in front of them starting to move.

Keywords: Horn use, Intersection, Traffic environment

1. INTRODUCTION

Horn sounds are acoustically designed to have high sound pressure levels so that vehicle drivers can be alerted to danger in a noisy environment. Therefore, frequent horn use is expected to contribute to noise problems near roads and streets. In fact, several countries face noise problems relating to frequent honking. Phan et al. reported that frequent horn honking is a major factor of road traffic noise in urban areas of Vietnam (1). Countermeasures for these problems, such as the reduction of horn use, are urgently needed.

To control driver horn use, it is necessary to clarify the causes of such use. Various intrinsic and extrinsic factors may affect horn use. Shinar regarded horn use as an indicator of driver aggression and investigated relationships between driver horn use and several factors including the duration that a driver has to wait for the vehicle in front to start moving, the level of traffic congestion, and the duration of green-light signals (2). Moreover, according to Fujii's socio-psychological model of

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drivers' traffic behaviors (3), certain behaviors are induced by behavioral intention, which are linked with psychological factors such as personal attitude (defined as preference), personal norms, perceived behavioral control (i.e., expectation concerning the ease of initiating certain traffic behaviors), and moral obligation. These results suggest that driver horn use, which is regarded as a traffic behavior, is affected by intrinsic (psychological) factors. A questionnaire survey conducted in South Korea (4) reported a relationship between drivers' psychological factors and the manner of horn use. Results revealed that drivers who did not usually use their horn were reluctant to do so, and that they generally briefly honked to alert another driver to danger or to gain their attention out of necessity.

Questionnaire surveys in Japan suggested that the traffic environment influences driver horn use, and found a relationship between the place and honking pattern of horn use, and the traffic volume and honking pattern (5). Driver horn use may be affected by extrinsic factors surrounding drivers. Accordingly, we propose a similar behavioral model of driver horn use, and suggest that intrinsic and extrinsic factors affect behavioral intention and evoke certain traffic behaviors including horn use, as shown in Figure 1. To solve noise problems relating to vehicle horn use, it is necessary to comprehensively understand the intrinsic and extrinsic factors leading to driver horn usage.

The present study focuses on the effects of extrinsic factors on driver horn use, which involve the transportation system and traffic environment such as traffic volume, road size, and traffic signals. We previously measured and recorded horn use and traffic circumstances (e.g., the traffic volume and traffic signals) at intersections in an urban area of Taiwan (6). Results revealed strong relationships between the traffic volume of standard-sized vehicles and the frequency of horn use. Furthermore, an analysis of the temporal variation of horn use during traffic signal cycles indicated that horn use increased when gridlock occurred. A further analysis was required to extract quantitative parameters related to the transportation system and traffic environment that affected horn use. In the present study, therefore, we conducted a detailed analysis to clarify causal reasons for driver horn use at the same intersections in the urban area of Taiwan that we previously studied.

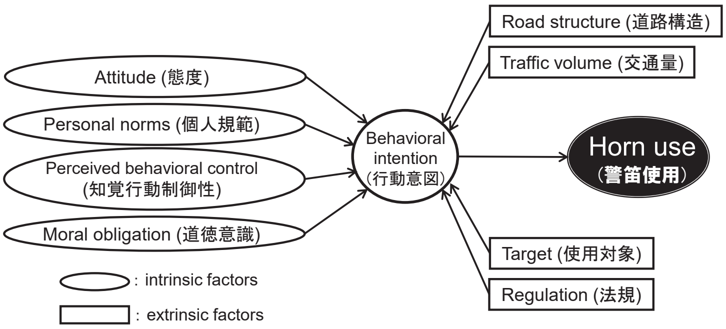

Figure 1 – Behavioral model of horn use adapted from a socio-psychological model (3). Various intrinsic and extrinsic factors influence driver behavioral intention and evoke horn use.

2. PROCEDURE

2.1 Survey sites and equipment

Our survey was carried out at three intersections (hereafter, Intersections 1 to 3) in Taipei. Noise measurements and noise recordings were continuously made over 12 hours (from 7:00 to 19:00) on one weekday and on one weekend day at each intersection. Figure 2 illustrates the surveyed intersections. Data from 10-minute spans in every hour (e.g., 7:20-7:30, 8:20-8:30, etc.) were extracted for analysis. Table 1 presents features of each intersection such as the number of lanes in each direction and the minimum and maximum total traffic volumes during the measurement periods for analysis (i.e., 10 minutes per hour).

To record the overall view of an intersection, including all vehicles passing through the intersection, two video cameras (SONY HDR-CX560V and SONY HDR-CX370) were set on a pedestrian bridge over or near an intersection. To measure the noise level of road traffic noise and to record the road traffic noise itself, a sound level meter (RION NL-52) was installed at a height of 1.5 m near the middle of the pedestrian bridge.

We analyzed traffic volume and road traffic noise recorded over 10-minute spans in every hour. To measure traffic volume, vehicles were categorized as motorcycles, standard-sized vehicles, and large-sized vehicles. Large-sized vehicles comprised specific vehicle types, such as buses and mixer trucks. Other vehicles, such as minibuses and light trucks, were classified as standard-sized vehicles.

The time at which drivers used their horn and the honking pattern of horn use were obtained through an analysis of road traffic noise using data management software (RION AS-60). Vehicle horn use and traffic volume data were analyzed in 10-minute periods.

Table 1 – Intersection features

	The number of lanes at an entrance (lanes exclusive to left turns) / lanes at an exit				Minimum total traffic volume ~ Maximum total traffic volume	
	North	South	West	East	Weekday	Weekend
Intersection 1	5(1)/4	5(2)/4	4(2)/3	3(0)/3	1020~1648	531~1135
Intersection 2	5(1)/4	3(1)/2	2(0)/2	2(1)/2	986~1839	621~1480
Intersection 3	4(1)/4	6(1)/4	3(1)/3	3(1)/3	747~1541	263~944

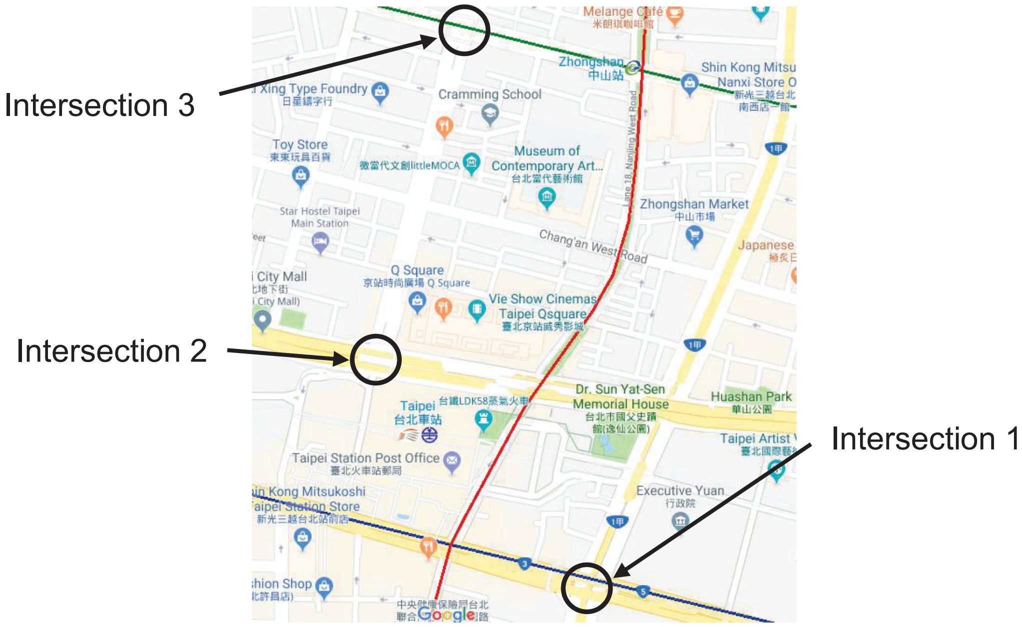

Figure 2 – Map of surveyed sites

3. ANALYSIS AND RESULTS

3.1 Horn honking during traffic signal cycles

Detailed situations when drivers used their horn during traffic signal cycles (i.e., from the onset of the green-light phase, indicated by "phase I", to the onset of the next cycle) were analyzed for each intersection. The traffic signal cycles were composed of four phases as shown in Figure 3. For instance, in Intersection 2, Roman numerals I to IV represent the green-light phase for straight travel in the east–west direction and turning right to the north (I), straight travel in the direction from west to east and turning left to the north (II), entry into the intersection from the north only (III), and entry into the intersection from the south only (IV). Table 2 gives green light durations in each phase and traffic signal cycle durations at each intersection. Such durations varied depending on measurement days and time zones.

Table 3 presents frequencies of driver horn use, which were counted during green-light phases in all measurement periods of every hour (i.e., the total duration of green light phases within the 10-minute periods for each of the 12 hours measured). The frequencies of honking on weekdays were generally higher than those on weekends. Many instances of horn use were found during phases I and II at Intersection 1, and during phases other than phase II at Intersection 2. At Intersection 3, the frequencies of horn use during phases II and III were higher than those during other phases.

As shown in Table 2, the green light duration was different among different phases, measurement days, and intersections. Therefore, the horn counting durations were equalized to 10 minute periods, and the frequencies of honking per 10-minute spans were extrapolated based on honking frequency within 1-second span measures in each of four green-light phases, which were averaged in all measurement periods and days. Table 4 shows the estimated honking frequencies in cases when each green-light phase was 10 minutes in duration. Results revealed that horn use was more frequent during phases I and II at Intersection 1, and during phases other than phase I at Intersection 2. At Intersection 3, horn use during phases I and IV seemed to be relatively large, although overall horn usage was lower compared with other intersections.

In green-light phases in which horn use was frequently recorded, such as phase II in Intersections 1 and 2, and phase IV in Intersection 3, drivers were allowed to turn left as well as going straight (e.g., in phase II in Intersections 1 and 2), as shown in Figure 3. According to our video analysis, there were many cases where honking began after vehicles entered the intersection to turn left during the green-light phase. Therefore, we next investigated the causes of driver horn use in situations when green-light signals allowed left turns.

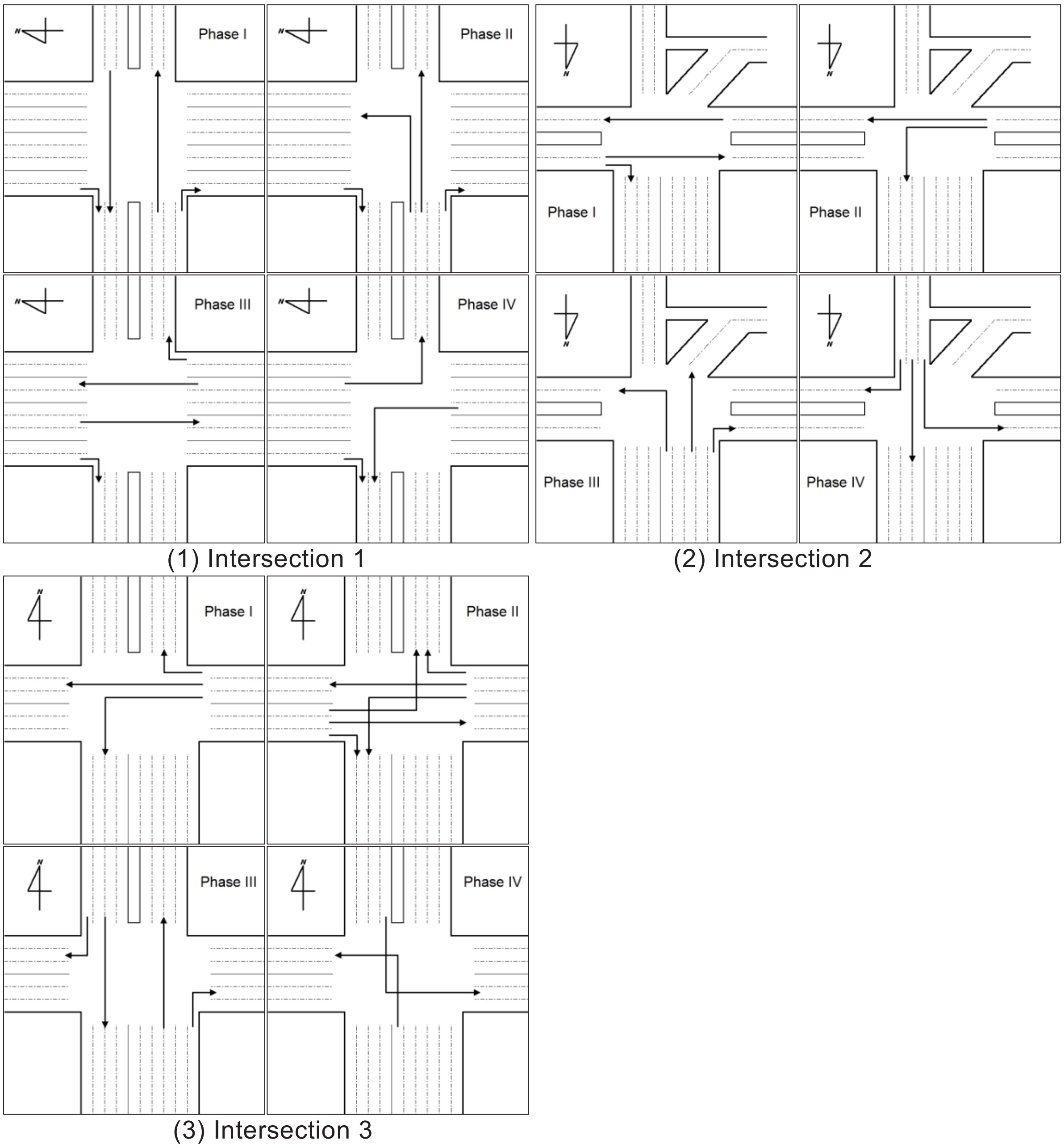

Figure 3 – Diagram of traffic flow in traffic signal cycles, which were composed of four green-light phases (I to IV) for straight travel or travel turning right or left

Table 2 – Green light duration during each phase and traffic signal cycle duration

	Green light duration on weekdays [seconds] / on weekends [seconds]				Traffic signal cycle duration [seconds]	
	Phase I	Phase II	Phase III	Phase IV	Weekday	Weekend
Intersection 1	35~45/36~45	41~46/29~37	72/41~47	42~47/30~38	200	150
Intersection 2	70~75/74~84	11~15/15	43~48/40	62~69/61~71	200	200
Intersection 3	15/15	65~85/45~55	70~85/50~60	30~35/25~30	200	150

Table 3 – Honking frequencies during green-light phases in all measurement periods of every hour

		Phase I	Phase II	Phase III	Phase IV
Intersection 1	Weekday	48	56	37	35
	Weekend	47	39	19	28
	Total	95	95	56	63
Intersection 2	Weekday	64	16	74	77
	Weekend	50	26	66	131
	Total	114	42	140	208
Intersection 3	Weekday	10	47	36	28
	Weekend	13	29	31	16
	Total	23	76	67	44

Table 4 – Estimated honking frequencies in cases when each green-light phase was 10 minutes in duration

	Phase I	Phase II	Phase III	Phase IV
Intersection 1	17	19	7	12
Intersection 2	13	25	27	25
Intersection 3	11	9	7	11

3.2 Analysis of instances of honking during the green-light phase allowing left turns and causes of driver horn use

We used video data to analyze instances of honking during the green-light phase allowing left turns (i.e., phase II at Intersections 1 and 2, and phase IV at Intersection 3). The scenarios when vehicle horns were used were first categorized into four types of situations including "breaking into a line", "slowness", "sudden stops" and "stopping state". In the situation of "breaking into a line", a driver of a car that breaks into a line to turn left is honked at by a driver of another car. In the situation of "slowness", a driver of a slowly moving car was honked at by another driver. The situation of "sudden stops" means that a driver used a horn when he/she had to stop suddenly due to a vehicle in front stopping. In the situation of "stopping state", a car at a stop line failed to start even though a green-light signal allowed left turns, leading to a driver of another car to honk. Table 5 gives frequencies of each situation when horns were used during the above-mentioned phases from every measurement period. Results indicated that horn uses in "stopping state" situations were frequently found at each intersection, although there were more cases in which detailed situations were unclear.

We next investigated the duration from the onset of the green-light phase to the timing when a car at the front of a stop line started moving (i.e., the start delay time) using video data. Afterward, the relationship between the start delay time and horn use was investigated during the green-light phase allowing left turns. There were two lanes for turning left in Intersection 1. In this intersection, therefore, a similar analysis was conducted in each lane. Table 6 shows the difference of the mean start delay time between situations with and without honking during the green-light phases allowing left turns at each intersection. Mean start delay times when a horn was used were longer than 4 seconds, although those when a horn was not used were around 2 seconds. T-tests were performed to determine the significance of differences in the mean start delay times. Results revealed that the differences in the mean start delay time between situations with and without honking were statistically significant. This result suggests that one of the major reasons that drivers used horns at intersections is the start delay of a vehicle in front of them.

Table 5 – Situation frequencies when horns were or were not used during green-light phases allowing left turns

	Types of situations when horns were used					Without honking
	Breaking into a line	Slowness	Sudden stop	Stopping state (delay)	Unclear	
Intersection 1	10	4	3	27	55	117
Intersection 2	2	3	1	24	14	34
Intersection 3	2	6	0	6	29	95

Table 6 – Mean start delay time with and without honking during green-light phases allowing left turns (**: $p<0.01$)

		Number of situations	Mean start delay time [seconds]	
Intersection 1	With honking	27	4.6	**
	Without honking	117	2.2	
Intersection 2	With honking	24	6.2	**
	Without honking	34	2.0	
Intersection 3	With honking	6	4.2	**
	Without honking	95	2.1	
All intersections	With honking	57	5.2	**
	Without honking	246	2.2	

3.3 Analysis of the relationship between driver horn use and the traffic environment

To clarify the main factors related to the traffic environment that affect driver horn use, logistic regression analysis was conducted using horn use as the dependent variable. Independent variables included the start delay time, traffic volumes of three types of vehicles (i.e., motorcycles, standard-sized vehicles, and large-sized vehicles), the duration of green-light signal allowing left turns, the number of left turn lanes, and the number of exit lanes. The start delay time and the traffic volume of standard-sized vehicles were statistically significant, suggesting that the probability of driver horn use increases as the start timing or the volume of standard-sized vehicle increases (Table 7). Furthermore, the probability of driver horn use may also increase as the duration of green-light signals allowing left turns decreases because this variable approached significance (p=0.063).

Table 7 – Logistic regression analysis of horn use (**: p<0.01, n.s.: not significant)

Independent variables	Regression coefficient	Significance	Odds ratio
Start delay time	0.514	**	1.672
Traffic volume of motorcycles	0.052	n.s.	1.054
Traffic volume of standard-sized vehicles	0.114	**	1.120
Traffic volume of large-sized vehicles	−0.028	n.s.	0.973
Duration of green-light signals for left turns	−0.094	n.s.	0.910
The number of lanes allowing left turns	−0.449	n.s.	0.638
The number of exiting lanes	0.237	n.s.	1.268

3.4 Effect of honking on the sonic environment around intersections

To clarify the effect of honking on the sonic environment around intersections, the A-weighted equivalent noise level ($L_{\mathrm{Aeq,10min}}$) and the maximum noise level value (L_{Amax}) of road traffic noise were investigated when vehicle horns were and were not used at intersections. $L_{\mathrm{Aeq,10min}}$ and L_{Amax} when horns were not used were calculated using data management software (RION AS-60). Noise level data corresponding to honking were deleted from the initial measures, and then values of $L_{\mathrm{Aeq,10min}}$ and L_{Amax} were recalculated. Figure 4 shows temporal variations of traffic volume and $L_{\mathrm{Aeq,10min}}$ at each measured hour of two measurement days at Intersection 1. Figure 5 shows results for L_{Amax}.

Relationships between $L_{\mathrm{Aeq,10min}}$ and traffic volume were statistically significant in all measurements other than one weekday at Intersection 1 (Intersection 1: r_{weekday}=−0.05, n.s.; r_{weekend}=0.81, p<0.01; Intersection 2: r_{weekday}=0.87, p<0.01; r_{weekend}=0.76, p<0.01; Intersection 3: r_{weekday}=0.62, p<0.05; r_{weekend}=0.85, p<0.01). Values of $L_{\mathrm{Aeq,10min}}$ when horns were not used were similar to those when horns were used. In temporal variations of L_{Amax}, values sometimes decreased when vehicle horns were not used, and the maximum reduction in L_{Amax} was about 8 dB in situations when values of $L_{\mathrm{Aeq,10min}}$ were relatively low (Figure 5).

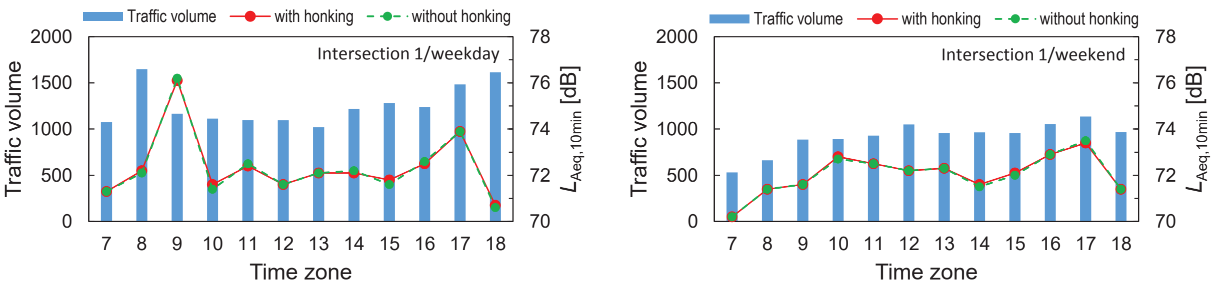

Figure 4 – Temporal variations of traffic volume and $L_{\mathrm{Aeq,10min}}$ at each measured hour at Intersection 1

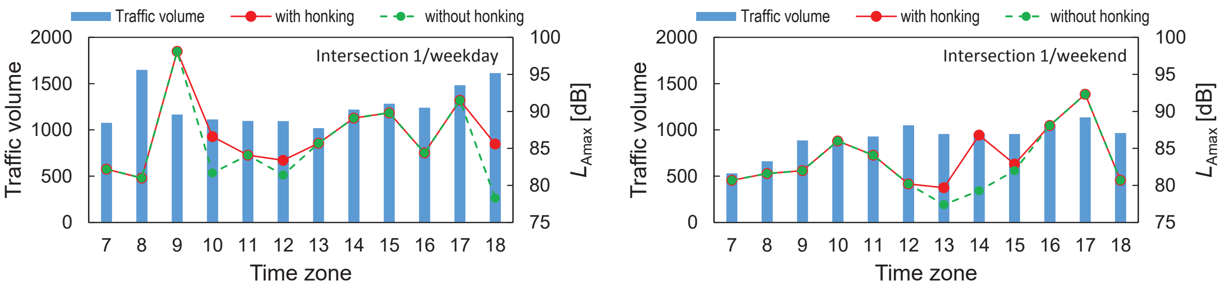

Figure 5 – Temporal variations of traffic volume and L_{Amax} at each measured hour at Intersection 1

4. DISCUSSION AND CONCLUSIONS

Our analysis of vehicle horn use at intersections indicated that horns were frequently used during green-light signals allowing left turns, and horns were frequently used in situations of "stopping states" at each intersection. Our results suggest that, when a vehicle at the stop line did not start moving as soon as the green-light signaled for left turns, other drivers used horns to request movement. These start delays were major causes of driver horn use. According to statistical tests of the differences of the mean start delay time between situations with and without honking during green-light phases allowing left turns, mean start delays when horns were used were significantly longer (Table 6).

Logistic regression analysis revealed that the start delay time and the traffic volume of standard-sized vehicles significantly affected driver horn use. Tsunekawa et al. also reported that the frequency of horn use generally increased as the traffic volume of standard-sized vehicles increased (6). Furthermore, the present results revealed that the start delay time was a major factor influencing driver horn use. Drivers sometimes missed the initial green-light signal and started driving late. In such situations, horn use from drivers in following cars was frequently detected. According to behavioral testing, driver horn reaction time was approximately 2 to 4 seconds when drivers were blocked by other cars after the green-light phase began during rush hours or weekends (2). Driver horn use is expected to decrease when other drivers quickly respond to traffic signals, and shorter green-light signal duration allowing left turns tends to increase driver horn use. Optimizing the duration of traffic signals may help to reduce horn use.

Results on temporal variations of noise level suggest that L_{Amax} sometimes decrease with reduced horn use in situations when values of $L_{\mathrm{Aeq,10min}}$ were relatively low. Although sonic environment near roads and streets will be improved as electric cars and hybrid vehicles become popular, horn uses supposedly make it worse.

According to the simulation when vehicle horns were not used, $L_{\mathrm{Aeq,10min}}$ did not change. The relationship between the number of honks per minute and the increase in road traffic noise (L_{Aeq}) indicates that honking more than twice per minute can affect L_{Aeq} (7). Results reported by Tsunekawa et al. revealed up to thirty-three honks within each 10-minute measurement period (Intersection 1: 23, Intersection 2: 33, Intersection 3: 17) (6). In the present study, therefore, results suggest that there are no attenuations in $L_{\mathrm{Aeq,10min}}$ under situations without honking.

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