BEHAVIOR AND CONSCIOUSNESS ANALYSES ON EFFECT OF TRAFFIC SIGNALS INCLUDING COUNTDOWN DEVICE FOR VEHICLES

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Abstract: It is expected to control traffic light safely, especially at inter-green periods because the drivers’ judgments whether pass or not at that time affect the occurrence of severe traffic conflicts. Recently, countdown-type traffic signals for vehicles that are contributory to make appropriate judgments have been installed positively in Asian countries. In this study, we conducted a questionnaire survey and observed surveys via video cameras at signalized intersections with those types of traffic signals installation in Turkey. Analyzing the effect of the traffic signal from the viewpoint of users’ consciousness, it was shown that users’ satisfaction is improved and driving rage is dropped by the countdown display. Furthermore, it was also found that start-up delay is reduced and risky behaviors at inter-green periods are decreased by the signal, but at the same time the inadequate signal parameter settings may induce risky behaviors in spite of the countdown-type traffic signal installation.

Key Words: Countdown device for vehicles, Risky behavior model, Users’ consciousness

1. INTRODUCTION

The long cycle lengths, like Japan, not only impose unnecessary delay upon users, but also often cause road users’ risky behaviors, such as rushing into intersection during yellow time and all-red time (hereinafter called inter-green periods) or ignoring a red light(SUZUKI et al.(2004), etc). Drivers’ judgments whether pass or not at inter-green periods may affect the occurrence of severe traffic conflict. Thus, it is necessary to set the time periods carefully.

In order to inhibit these risky behaviors, it is expected to control the traffic signal appropriately in consideration of the relationship between users’ consciousness and their behaviors. Besides the setting of traffic signal parameters, it is considered that the traffic lights with countdown device, which have been installed rapidly in recent years in Asian countries as shown in Figure 1 and Figure 2, are expected to be an effective countermeasure for curbing road users’ impatience and cutting down their errors in judgment at inter-green periods though these effects have not assessed quantitatively yet. In addition, there are no traffic signals with the device for vehicles in Japan. Therefore, if there are the desired effects,
it can be a countermeasure to solve the problems at inter-green periods.

For green signal countdown device for vehicles, Lum et al. (2005) measured the effect of installation of the device from the viewpoint of red light running rate and stopping rate based on before-after analysis and revealed the usefulness of the device under the heavy traffic condition. However, it remains several issues such as analysis on the relationship among installations of the device, traffic signal control settings and change in users’ consciousness.

For red/green signal countdown device for pedestrians, there are several previous researches. For example, Keegan et al. (2003) analyzed the effect of installation of the device in Dublin based on before-after surveys, such as hearing investigation and observation survey, and concluded that the risky crossings were reduced by the device installation. On the other hand, Ieda et al. (2002) evaluated the impact of the red signal countdown device on pedestrians from both physiological and psychological aspects by using a walking simulator with virtual reality technologies and Yano et al. (1998) revealed that it is desirable to operate each intersection in considering the variation with time of traffic conditions or the change in traffic characteristics by the purpose of road users differences based on the hearing and observation survey. Murata et al. (2007) proposed a new display of remaining green time to ensure safe crossing of pedestrians and evaluated the method by field test.

In this study, we focus on the green/red countdown device for vehicles, which has operated at signalized intersection in Turkey, where one of the authors could get the collaboration of local authority and discuss the impact of the device on traffic flow at signalized intersection by using observation data via digital video camera recorders. Especially we analyze the vehicle behaviors at inter-green period in detail. And we also examine the relationship among the countdown device, road users’ consciousness and their behaviors based on questionnaire survey. That is, the objective of this study is to reveal the basic characteristics of the countdown device for vehicles from the standpoints of not only the vehicle behaviors but also drivers’ consciousness.
2. OUTLINE OF SURVEYS AND TRAFFIC CONDITIONS OF THE SURVEY DATE

We conducted observation surveys via digital video camera recorders at two signalized intersections in Kayseri city, Turkey: one intersection has installed the traffic signal with countdown device for vehicles (hereinafter called Emek intersection) and another has not installed the signal (hereinafter called Sanai intersection). The placement of video camera recorders are as follows: the equipments were set in the adjacent building at Emek intersection as shown in Figure 3, and placed on sidewalk near the Sanai intersection (see Figure 4). The characteristics of these intersections are shown in Table 1. Hourly traffic volume at Emek as a typical traffic condition and the signal phasing at Emek intersection are also shown in Figure 5. Both outlines and the result of questionnaire survey for investigating users’ perceptions are shown in Chapter 5.

Table 1 Description of the intersections for investigation

<table>
<thead>
<tr>
<th>Intersection</th>
<th>Date</th>
<th>Time</th>
<th>Number of lanes</th>
<th>Cycle length (green time: EBWB / SBNB) [sec]</th>
<th>Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emek</td>
<td>July 6-7, 2005</td>
<td>8:00-10:00, 16:30-18:30</td>
<td>3 3</td>
<td>87 (see Figure 5)</td>
<td>4</td>
</tr>
<tr>
<td>Sanai</td>
<td>November 17-18, 2004</td>
<td>8:00-10:00, 16:30-18:30</td>
<td>2 2</td>
<td>52 (20 / 26)*</td>
<td>2</td>
</tr>
</tbody>
</table>

*Yellow time + All-Red time for each phase: 3[sec], italics: subject in this study

Figure 5 Hourly traffic volume and phase plan at Emek intersection on the July 6th from 17:30 to 18:30
From the figure, Leg (a), which is from city center to the suburbs, has relatively high level of traffic volume at evening peak hours, but flow ratio of the intersection was 0.72, therefore serious traffic congestion didn’t occur. Moreover, at Emek intersection, four phase control in rotation, which is given the right-of-way for each leg, is adopted as shown in the figure, whereas typical two phase control was adopted at Sanai intersection. And countdown device of Emek intersection is displayed by seconds until just before the green or red light to change. On the other hand, hourly traffic volume for one approach at Sanai intersection was 730 and percentage of heavy vehicles was 17.8 percent.

In this study, two legs at Emek intersection (leg(a) and leg(d)) and one leg at Sanai intersection are analyzed by using the obtained image data. There are several differences in the signal control conditions and the existence of countdown device among these three legs as shown in Table 1 and Figure 5, therefore we have to analyze carefully with these differences.

3. ANALYSIS ON START-UP BEHAVIORS FOR VEHICLES AT SIGNALIZED INTERSECTIONS IN CONSIDERATION OF COUNTDOWN DEVICE

3.1 Distribution of start-up delay for the lead vehicle

For both intersections with or without countdown device, the start-up delay, which means the time lag from the beginning of green to the lead vehicle starting to move, was measured. The distribution of start-up delay for the lead vehicle is shown in Figure 6.

It is found that the start-up delay of both leg(a) and leg(d) of Emek intersection is smaller than that of Sanai intersection, but high proportion of hurry start (hereinafter called HS), which means the lead vehicle started moving before the beginning of green, at Emek intersection are also indicated. Besides that, compared the start-up delay of leg(a) with that of leg(d) at Emek intersection, it is shown that the value of leg(d) is smaller than that of leg(a).

![Figure 6 Distribution of start-up delay for each leg](image-url)
And it is also found that the rate of HS of leg(d) is 35.1 percent whereas that of leg(a) is 6.1 percent. This is because that drivers of leg(d) are frustrated by the red time, which is longer than that of leg(a) (see Figure 5).

3.2 Model analysis on the factors affecting the start-up behaviors at signalized intersection

3.2.1 Analysis on the factors of the start-up delay

In order to clarify the effect factors of the start-up delay of the lead vehicle, multiple regression analysis is conducted with the following variables:
- dummy variable of with or without countdown device (Emek intersection:1, Sanai intersection:0),
- dummy variable of vehicle type of the lead vehicle (heavy vehicle:1, others: 0),
- dummy variable of stopping place (if the vehicle stopped over the stop line:1, others:0),
- dummy variable of the vehicle existence of the crossing road (if the vehicle exists in the intersection during all-red time:1, others:0),
- the waiting time during the vehicle arrives the stop line and starts moving as explanatory variables.

In addition, in order to estimate the only start-up delay, the vehicles’ data of HS are eliminated in this case. The estimated result is shown in Table 2.

<table>
<thead>
<tr>
<th>Explanatory variables</th>
<th>Parameter (t-statistics)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dummy variable of with or without countdown device (Emek:1, Sanai:0)</td>
<td>-1.354(-4.35)</td>
</tr>
<tr>
<td>Dummy variable of vehicle type of the lead vehicle (heavy vehicle:1, others: 0)</td>
<td>0.792(2.49)</td>
</tr>
<tr>
<td>Dummy variable of the existence of the crossing roads (if the vehicle exists in the intersection during all-red time:1, others: 0)</td>
<td>0.582(1.25)</td>
</tr>
<tr>
<td>Constant</td>
<td>2.479(12.2)</td>
</tr>
<tr>
<td>Multiple correlation coefficient</td>
<td>0.568</td>
</tr>
<tr>
<td>F-statistic*</td>
<td>9.687</td>
</tr>
</tbody>
</table>

*level of significance: $F_{0.05(3,61)} = 2.75$

From the result, it is found that F-value is statistically significant though the multiple correlation coefficients might be not enough. From the estimated parameters, the following points are suggested:
- The waiting time that affected by signal parameter settings is not effective but the existence of countdown display is effective in reducing the start-up delay
- If the leading vehicle type is heavy vehicle, start-up delay tends to increase
- Existence of the vehicle of crossing direction in the intersection during all red time affects the increase in start-up delay though the result was not statistically-significant

3.2.2 Analysis on the factors of HS

We perform discriminant analysis in order to clarify the generating mechanism of HS before green signal starts. The criterion of HS is whether the start-up delay is negative value or not as shown in Figure 6 and these values are used in this analysis. Here, the following linear discriminant function model is adopted:

$$Z_f = \alpha_1 X_1 + \alpha_2 X_2 + \cdots + \alpha_n X_n$$  \hfill (1)

Where
$Z_f$: discrimination score,  $X_i$: explanatory variables $(i=1,2,\cdots,n)$,  
$\alpha_j$: parameters $(j=1,2,\cdots,n)$

Explanatory variables in this analysis are the same as the analysis on the factors of the start-up delay in the previous section. The estimated result is shown in Table 3. It can be said that the accuracy of the model is sufficiently high from the results of hit ratio and chi-square test.

From the result, the existence of countdown device also has an impact on conducting HS behavior, and signal delay exerts a similar influence, too. That is, drivers tend to judge the HS behavior both at the signalized intersection with countdown display and under the large signal delay. In addition, the parameter of vehicle type of the lead vehicle is negative. This means heavy vehicles tend not to move before green signal starts because of the low acceleration performance.

It is summarized that countdown display at signalized intersection affects reducing start-up delay whereas there is a possibility of increasing HS behaviors on the setting of inappropriate traffic signal parameters in this chapter.

### Table 3 Result of discriminant analysis on HS behaviors (number of samples: 78)

<table>
<thead>
<tr>
<th>Explanatory variables</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dummy variable of with or without countdown device (Emek:1, Sanai:0)</td>
<td>0.542</td>
</tr>
<tr>
<td>Dummy variable of vehicle type of the lead vehicle (heavy vehicle:1, others:0)</td>
<td>-0.183</td>
</tr>
<tr>
<td>Dummy variable of stopping place (if the vehicle stopped over the stop line:1, others:0)</td>
<td>-0.013</td>
</tr>
<tr>
<td>Dummy variable of the existence of the crossing roads (if the vehicle exists in the intersection during all-red time:1, others: 0)</td>
<td>0.682</td>
</tr>
<tr>
<td>Delay</td>
<td>0.254</td>
</tr>
<tr>
<td>Hit ratio [%]</td>
<td>80.8</td>
</tr>
<tr>
<td>$\chi^2$-statistic*</td>
<td>32.1</td>
</tr>
<tr>
<td>Significance probability</td>
<td>0.000</td>
</tr>
</tbody>
</table>

*level of significance: $\chi^2$-statistic=3.84

4. ANALYSIS ON RISKY BEHAVIORS AT INTER-GREEN PERIODS

4.1 Approach speed during clearance interval

4.1.1 Specification of analysis objects

For Emek intersection, traffic streams were recorded by several video camera recorders, which were located on a building during the time of the observation survey. Therefore, we can analyze from the stop line to 50m upstream at the intersection. On the other hand, for Sanai intersection, since we couldn’t record the moving video pictures from a high position due to existing no building in the surrounding at the intersection, we can use only 10m upstream from the stop line. Therefore, we treat and analyze the range from stop line to 10m upstream for both intersections.

In this chapter, we analyze the vehicles that pass or stop at the timing from the beginning of amber to the end of all-red time.
4.1.2 Comparative analysis on the approach speed at inter-green periods

Here, it is compared the distribution of approach speed at Emek intersection to that of approach speed at Sanai intersection. In addition, the approach speed for each leg, which was measured at the 5m upstream from the stop line, is used.

Figure 7 shows approach speed of the vehicles that pass from the beginning of amber to the end of all-red interval, and Figure 8 shows approach speed of the vehicles that stop from the same interval.

It is calculated that average approach speed of the all vehicles for leg (a) at Emek intersection is 22.4 km/hr (standard deviation (hereinafter called “SD”): 9.43), the speed for leg (d) at Emek intersection is 24.1 km/hr (SD: 11.6), and the value at Sanai intersection is 18.1 km/hr (SD: 7.90). We analyze the characteristics of two kinds of approach speeds measured by the stopped vehicles and the passed vehicles during the interval.

From the Figure 7, as for one reason of differences between the mean value of Emek intersection and that of Sanai intersection, drivers at Emek intersection can understand the
remaining green time to red signal precisely because the countdown is displayed until just before the green light changes. Hence, it is thought that they tend to judge the risky behaviors because they can adjust their speed with considering the relationship between their position at the beginning of yellow light and the remaining time.

On the other hand, as for the approach speed for the stopped vehicles, it is found that the value of Emek intersection is slightly higher than that of Sanai intersection. For leg(d) at Emek intersection, there are the vehicles over 15km/hr, and it is shown that the approach speed varies widely. These results indicate that countdown device can delay drivers’ judgment not only to pass the stop line but also to stop at the intersection. The other factor is that signal control delay of leg(d) is larger than the other two legs.

Therefore, it is revealed that the countdown display and the inadequate traffic signal control may be conducive to the risky behavior such as rushing into intersection and rapid deceleration at inter-green period for the high-speed drivers.

4.2 Analysis on rushing into intersection at inter-green periods

4.2.1 Rate of rushing into intersection at inter-green periods

Here, we define two indices as below in order to recognize the proportion of occurrence of risky behaviors after amber: one is the proportion of the vehicles that passed the stop line during yellow time, and another is the proportion of the vehicles that passed the stop line during all-red time.

\[ P_{amber} = \frac{Q_{amber}}{Q_{total}} \]  \hspace{1cm} (2)

\[ P_{red} = \frac{Q_{red}}{Q_{total}} \]  \hspace{1cm} (3)

Where \( P_{amber} \): Proportion of the vehicles that passed the stop line during yellow time, 
\( Q_{amber} \): Number of the vehicles that passed the stop line during yellow time,
\( Q_{total} \): Number of the vehicles that arrived the range from the stop line to 10m upstream the line during yellow and all-red interval 
\( P_{red} \): Proportion of the vehicles that passed the stop line during all-red time, 
\( Q_{red} \): Number of the vehicles that passed the stop line during all-red time 

![Figure 9 Rate of rushing into intersection at inter-green periods for each leg](image-url)
The calculated results of these proportions for each leg are shown in Figure 9.

It is observed that $P_{\text{amber}}$ of leg (d) at Emek intersection is slightly higher than that of leg (a), and especially $P_{\text{red}}$ of leg (d) is also higher than that of leg(a). This is because drivers empirically understand the red time of leg (d) is long and they need waiting for the next green signal. Moreover, it is considered that this result also affects the start-up delay differences of two legs as shown in Figure 6. That is, since there are large number of the vehicles that pass through during all-red interval at leg(d), the waiting vehicles at leg(a) are affected by these risky drivers at leg(d).

On the other hand, proportion of the vehicles that passed the stop line during yellow time and all-red time at Sanai intersection, is slightly higher than the other two legs.

4.2.2 Modeling the drivers’ judgments whether taking risky behaviors or not at inter-green periods

The probability of the judgments whether taking risky behaviors or not at inter-green periods can be explained by logistic regression model.

\[ P_{\text{pass}} = \frac{e^{V_{\text{pass}}}}{1 + e^{V_{\text{pass}}}} \]  
\[ V_{\text{pass}} = \alpha_1 X_1 + \alpha_2 X_2 + \cdots + \alpha_n X_n \]

Where
- $V_{\text{pass}}$: utility function of passing the intersection at inter-green periods
- $X_i$: explanatory variables ($i=1,2,\ldots,n$)
- $\alpha_j$: parameters ($j=1,2,\ldots,n$)

As explaining variables in this time, the following variables are used:
- Dummy variable of with or without countdown device (Emek: 1, Sanai: 0)
- Approach speed [km/hr]
- Delay [sec]
- Dummy variable of existence of the front vehicle (the case of the front vehicle existed in the range from the bumper of the target vehicle to 10m downstream the vehicle:1, others:0 )
- Dummy variables of the vehicle type (heavy vehicle:1, others:0)
- Elapsed time from the beginning of amber when the vehicle arrived at the object zone
- Constant

Result of the parameter estimation is shown in Table 4. From the result, it is found that both likelihood ratio and hit ratio of all models are enough high.

Firstly, as for model1, the parameter of the existence of countdown device is negative. This means that countdown display affects reducing the rushing into intersection. In addition, the parameter of elapsed time from the beginning of amber is also negative. This result is that if elapsed time from the beginning of amber is long, drivers tend to stop at inter-green periods in order to avoid their dangers. On the other hand, since the parameter of approach speed is positive, this means that the higher approach speed, the easier to take risky behaviors. It can be said that these results are rational.

Secondly, from the results of model2, model3 and model4, since the dummy variable of with or without countdown device is not included due to analyze the data for each leg separately, the approach speed is the most effect factor of these models. Parameters of the elapsed time in

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2297
these models have similar effects to model1, and rational. As for the ratio of the parameter of approach speed to that of elapsed time from the beginning of amber for each model, the value of leg(a) is larger than that of the other two legs (the ratio of leg(a)=6.74, leg(d)=3.86, Sanai=3.83). It can be said that the elapsed time from the beginning of amber that might be affect severe traffic conflict are underestimated at Sanai intersection and leg(d).

Finally, for the model5, it is observed that the parameter of delay is positive. This means that the larger delay affects the increase of risky behaviors. By comparison of the parameters between countdown device and delay, it is found that the existence of countdown device is equivalent to 23.9 seconds in delay. For this model, since a strong correlation between delay and approach speed was shown, the approach speed was not adopted as an explanatory variable.

Therefore, it is revealed that the countdown display can contribute to inhibit the rushing into intersection at inter-green periods, whereas the display may bring about the possibility of the risky behavior under inappropriate parameter settings of traffic signals.

4.2.3 Sensitivity analysis of risky behavior models

As shown in the previous sections, risk-taking behaviors for drivers at inter-green periods are quantitatively explained by the elapsed time from the beginning of amber, dummy variable of with or without countdown device, approach speed and delay. Here, sensitivity analysis of these variables to the risk taking behaviors is tested. Firstly, the following scenarios are assumed for model1.

case1: After 3 seconds passed from the beginning of amber, with countdown device
case2: After 3 seconds passed from the beginning of amber, without countdown device
case3: After 5 seconds passed from the beginning of amber, with countdown device
case4: After 5 seconds passed from the beginning of amber, without countdown device

For each case, the relationship between probability of rushing into intersection and approach speed are analyzed and the result is shown in Figure 10.
The figure shows that the higher approach speed, the higher $P_{\text{pass}}$ at inter-green periods. In addition, it is observed that $P_{\text{pass}}$ reaches nearly 1.0 if the approach speed exceeds 20 km/hr in the case of without countdown device. On the other hand, it is found that $P_{\text{pass}}$ for the case of the same approach speed becomes lower if countdown device is placed by comparison between case.1 and case.2 or case.3 and case.4. Hence, the existence of countdown display can support drivers to prepare their stops safely.

Furthermore, the following scenarios at Emek intersection are assumed that delay would decrease by 20% compared with the current condition by shortening the cycle length and delay would adversely increase by 20% compared with the current condition. The result is shown in Figure 11.

- case.1: delay would decrease by 20% compared with the current condition
- case.2: the current condition (average delay: 63.5 [sec])
- case.3: delay would increase by 20% compared with the current condition

From the figure, it is shown that $P_{\text{pass}}$ was about 0.7 after 3 seconds passed from the beginning of amber at the current condition, while the value of case.3 was over 0.9 and that of case.1...
was 0.46. That means a little bit of increase or decrease in delay affects the probability of risky behaviors. Therefore, it can be said that we can improve safer operation at inter-green by controlling the delay appropriately at the same time at the intersection with the countdown device. Moreover, from the comparison between case.1 and case.2, the differences between the elapsed time of case.1 and that of case.2 when both cases become the same value of $P_{\text{pass}}$ is about 1.3 seconds. This value is significant for the safety at intersection since the difference of 1.3 seconds is equivalent to 10m movements with the considering approach speed.

5. CONSCIOUSNESS ANALYSIS ON TRAFFIC SIGNAL WITH COUNTDOWN DEVICE

5.1 Outline of questionnaire survey for traffic signals with countdown device
In this chapter, we would verify the effect of the traffic signal with countdown device from viewpoint of the drivers’ consciousness based on the questionnaire survey conducted in the area where there are a lot of traffic signals with countdown device in Turkey. The outline of the investigation of the questionnaire is shown in Table 5.

<table>
<thead>
<tr>
<th>Items</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date</td>
<td>From November 20 to 27, 2004</td>
</tr>
<tr>
<td>Method of questionnaire survey</td>
<td>Door-to-door survey was conducted for the residents who experience the traffic signal with countdown device everyday in the city center of Kayseri by local investigators. The respondents were selected at random.</td>
</tr>
<tr>
<td>Number of samples</td>
<td>201</td>
</tr>
</tbody>
</table>

(1) Attributes:
Age, Gender, Length of driving experience, Driving frequency

(2) Effect of installing traffic signals with countdown device:
- Irritation when they wait for the traffic light
  (Very decreased, Somewhat decreased, Comparable level, Modestly increased, Increased substantially)
- Number of tooting horn at traffic lights
  (Very decreased, Somewhat decreased, Comparable level, Modestly increased, Increased substantially)
- Speed in starting a vehicle
  (Very quicken, Somewhat quicken, Comparable level, Rather slow, Very slow)
- Conditions when they pass during green time
  (He/she can pass well in advance, He/she can pass with some margin, comparable level, He/she passes without some margin, He/she passes in a hurry)
- Conditions when they stop at a red light
  (He/she can stop well in advance, He/she can stop with some margin, comparable level, He/she stops without some margin, He/she stops in a hurry)
- Degree of satisfaction
  (Dissatisfied, Somewhat dissatisfied, Medium, Fairly satisfied, Satisfied)
5.2 Aggregate analysis on users’ consciousness about traffic signals with countdown device

Firstly, the result of effect of traffic signals with countdown device is shown in Figure 12.

From the figure (a), almost 80 percent of respondents evaluated “reduced the frustration when they wait the next green”, that is to say, it can be considered that there is an effect to which the waiting time display of countdown device calm down driver's psychological condition. Figure(b) shows the frequency of tooting horn at traffic lights was reduced by the countdown display, and it can be said that the countdown device is also contribute to the reduction of irritation and the aggressiveness of the driver. From the figure (c), it is observed that 64

-very decreased
-somewhat decreased
-comparable level
-modestly increased
-increased substantially

Figure 12 Aggregate analyses on the effect of installation of countdown signals
percent of respondents tend to hasten the onset of the start preparation. Moreover, over 80 percent of respondents pass at ease during green time as shown in figure (d), whereas a similar percentage also stops calmly at changing into red (figure (e)). From the figure (f), over 80 percent of respondents evaluated “satisfied” or “fairly satisfied” and 97 percent did positive evaluation for traffic signals with countdown device when “normal” is added. It is confirmed that the countdown type signal has a positive effect for users from the viewpoint of users’ consciousness.

5.3 Covariance structure analysis for the satisfaction of traffic signals with countdown device

Then, it is clarified the impact of traffic signals with countdown device on the users’ comprehensive evaluation by using the covariance structure analysis. Latent variables and observed variables are shown in Table 6, and the path diagram of the optimum model is also shown in Figure 13. The number of data used in the analysis was n=201. Latent variables are “Attributes”, “Conditions when they wait for the traffic light to change and start” and “Conditions when they pass or stop the intersection”.

<table>
<thead>
<tr>
<th>Latent variables</th>
<th>Observed variables</th>
<th>Choices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attributes</td>
<td>Gender</td>
<td>Male:1, Female:2</td>
</tr>
<tr>
<td></td>
<td>License holding</td>
<td>Unlicensed driver:0, Licensed driver:1</td>
</tr>
<tr>
<td></td>
<td>Age</td>
<td>10’s: 1, 20’s: 2, 30’s: 3, 40’s: 4, 50’s: 5, 60’s: 6</td>
</tr>
<tr>
<td></td>
<td>Driving frequency</td>
<td>Everyday:1, Two times per week:2, One time per week: 3, Two times per month:4, Not use:5</td>
</tr>
<tr>
<td>Conditions when they wait for the traffic light to change and start</td>
<td>Irritation when they wait for the traffic light</td>
<td>Very decreased:1, Somewhat decreased:2, Comparable level:3, Modestly increased:4, Increased substantially:5</td>
</tr>
<tr>
<td></td>
<td>Number of tooting horn at traffic lights</td>
<td>Very decreased:1, Somewhat decreased:2, Comparable level:3, Modestly increased:4, Increased substantially:5</td>
</tr>
<tr>
<td></td>
<td>Speed in starting a vehicle</td>
<td>Very quicken:1, Somewhat quicken:2, Comparable level:3, Rather slow:4, Very slow:5</td>
</tr>
<tr>
<td>Conditions when they pass or stop the intersection</td>
<td>Conditions when they pass during green time</td>
<td>He/she can pass well in advance:1, He/she can pass with some margin:2, comparable level:3, He/she passes without some margin:4, He/she passes in a hurry:5</td>
</tr>
<tr>
<td></td>
<td>Conditions when they stop at a red light</td>
<td>He/she can stop well in advance:1, He/she can stop with some margin:2, comparable level:3, He/she stops without some margin:4, He/she stops in a hurry:5</td>
</tr>
<tr>
<td></td>
<td>Comprehensive evaluation</td>
<td>Dissatisfied:1, Somewhat dissatisfied:2, Medium:3, Fairly satisfied:4, Satisfied:5</td>
</tr>
</tbody>
</table>

From the figure, it can be said that the accuracy of this model is comparatively good because the GFI (Goodness of Fit Index) was 0.946 and the AGFI (Adjusted Goodness of Fit Index) was 0.904.

As for “Attributes”, it is found that “driving frequency” is strongly associated with “comprehensive evaluation”. This means drivers who drive frequently feel satisfied with ease
because the more effects are obtained by the countdown display.

For “Conditions when they wait for the traffic light to change and start”, it is understood that “irritation when they wait for the traffic light” and “number of toot horn at traffic lights” have greatly influence on “comprehensive evaluation”. The former means that getting to know the remaining time to change the signal precisely reduces the irritation. The latter is because start-up delay was decreased by countdown display as shown in Figure 6 and as a result the number of tooting horn at traffic lights was decreased simultaneously. From these results, comprehensive evaluation becomes higher by installing the countdown type traffic signals.

6. CONCLUSION

The conclusions of this paper can be summarized as below:

- It was found that countdown display at signalized intersection affects reducing start-up delay and smoothing traffic flow whereas there are risky drivers, who accelerated near the intersection intently because of the countdown timer was displayed until right before the light to change. Therefore, it is necessary for installation of the countdown type traffic signals to discuss the way of displaying the countdown timer with considering traffic safety.
- It was cleared that countdown display can contribute to inhibit the rushing into intersection at inter-green periods, whereas the display may bring about the possibility of the risky behavior under inappropriate traffic signal control, such as with suffering unnecessary long delay.
-It was shown that drivers’ irritation at signalized intersections was reduced by getting to know the remaining time to change the signal precisely, and the countdown display has an effect on calming driver’s state of mind. Decreasing the number of tooting horn at signalized intersections also proved this result, and the countdown display affects the reducing driver’s aggressiveness.

-It was confirmed that the countdown type signal has a positive effect for users’ comfort from both results the conditions when drivers pass during green time and the conditions when they stop at a red light.

Though much scientific knowledge was shown in this study, the estimated drivers’ judgment model remains the issue for enriching the number of data. And it must be noted that the results of Turkish cases do not always agree with Japanese situation because of the matter of difference in national character. In addition, further detailed analyses on vehicle’s behaviors are expected at more intersections: not only the parameter settings of traffic signals and the geometric conditions of intersection for reducing drivers’ risky behaviors such as HS and rushing into intersection at inter-green periods will be discussed, but also the impacts on environmental aspect by installing the countdown traffic signals will be evaluated quantitatively.

REFERENCES


