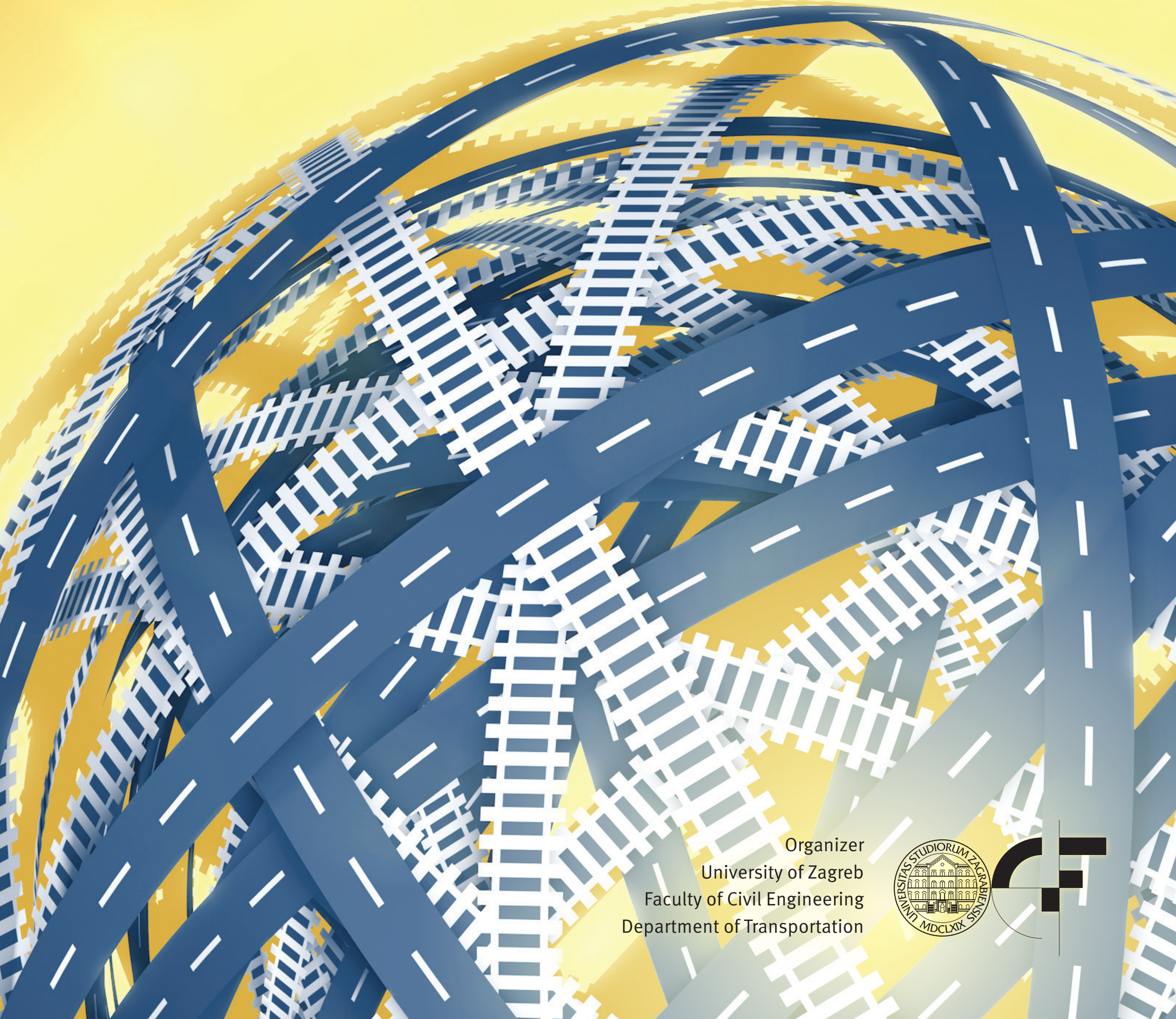
CETRA2016

4th International Conference on Road and Rail Infrastructure
23–25 May 2016, Šibenik, Croatia

Road and Rail Infrastructure IV

Stjepan Lakušić – EDITOR



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EDITOR
Stjepan Lakušić
Department of Transportation
Faculty of Civil Engineering
University of Zagreb
Zagreb, Croatia

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ANALYSIS OF HEADWAY CHARACTERISTICS IN DISSIPATING QUEUES

András Szele[1], Árpád Barsi[2], Lajos Kisgyörgy[2]
[1] *Institute for Transport Sciences, Hungary*
[2] *Budapest University of Technology and Economics, Hungary*

Abstract

Congestion related traffic flow management requires the thorough analysis of dynamics of queues to develop effective control strategies. Traffic operation of signalized intersections is often hindered by congestions. Queues cause an additional delay decreasing the capacity of the intersection, because in dissipating queues the headways are longer than in saturated flows. Thorough analysis of dynamics of queue development and dissipation is important, because precise estimation of start-up lost times of dissipating queues can help to minimize this capacity decrease due to the presence of queues. This paper analyzes the dynamics of queue dissipation and its major influencing factors. Queue dynamics data were collected in several locations in Budapest, Hungary using action cameras. We used exploratory data analysis to determine the principal components behind headway increments in dissipating queues and their importance. We identified those components which correlates to the traffic flow characteristics and can be influenced by traffic management tools.

Keywords: headway, queue dissipation, queue discharge, image analysis, congestion management

1 Introduction

Congestions in modern cities are the normal way of traffic operation nowadays. Congestions and congesting traffic operation cannot be efficiently managed by the traditional tools of traffic engineering, they require a different, a congestion related approach. The congestion related approach accepts congestions, tries managing instead of avoiding them [1].
Congestion relating flow management requires the thorough analysis of dynamics of queues to develop effective control strategies. Queues are inherent features of congestions, their formation and dissipation takes more time than the normal operation of traffic. If the dynamics of queue dissipation was fully understood it could be influenced by traffic control tools to increase the efficiency of traffic operation and decrease the delay. Adequate queue discharge/delay models are essential to the analysis and optimization of signal control strategies as well [2, 3].
Headway inside the dissipating queue is one of the dynamical features of interest, because it directly related to delay. In the literature several studies can be found on headway, however their findings are conflicting. Each of them confirms the start-up lost time at the first few vehicles, but after that the paths diverge. One group of the studies finds no change in headway values. HCM 2010 assumes a constant headway after the first few vehicles [4], which assumption is confirmed by some studies [5, 6]. However other researchers reported compressing headway along the dissipating queue [7-13]. They account this phenomenon for the tailgating and hurrying drivers at the end of the queue. On the other hand other studies found the headway would get longer after a certain point of time as the queue dissipating [14-17]

These contradicting findings imply that some traffic operational parameters influence the dynamics of queue dissipation, so more explanatory queue dissipation models are needed. Rouhani analyzed the effect of these parameters, ignored in the usual queue dissipating models and analysis, on the dissipation of queues in signalized intersections [18]. He concluded that the dynamics does not depend solely on location but on other factors such as green time and ratio of heavy vehicles as well.

Measuring headway is far from trivial. Traffic monitoring cameras and evaluating software do exist, but they are usually immobile. In our research we developed a method for commonly used action cameras, which is very suitable for determining traffic operation parameters easily, conveniently and effectively at almost any location.

This paper introduces an innovative solution to measure headways and tries to identify the principal components which influence them. Queue dynamics data were collected in locations in Budapest, Hungary using action cameras. We used exploratory data analysis to determine the principal components behind headway increments in dissipating queues and their importance, and we identified those components which correlates to the traffic flow characteristics and can be influenced by traffic management tools.

2 Methodology

In this research we examined the effect of certain factors on the headway in dissipating queues formed during the red sign. The location, the lane configuration and the type of traffic operation were included into the analyses. Locations and time of the analysis were chosen to represent these factors. We examined the effect of lane configuration by comparing the traffic operation of a one-lane direction to the traffic operation of the lanes of a two-lane direction. We analyzed if there is any difference in queue dissipation between the case of the single lane, of the right lane and of the left lane case. We also include a left turning lane and an on-ramp to the analysis.

We set the measure period when the traffic operation was congested. We defined the traffic operation congested if all the queuing vehicles could not go through the green light. The influence of the parameters was evaluated by analysis of variance.

3 Data collection method

The data collection was made by recording videos about the discharging traffic queues then the headways for different queue positions were determined by image analysis. Data collection time periods focused on the morning rush hours, under normal weather and traffic conditions. The applied system was an SJ4000+ action camera made by SJCAM. The camera has a lens of 2.99 mm focal length; the field of view is 170°. The camera is able to record videos with a resolution of 2K (2048 × 1080 pixels), but actually we had it with full HD (1920 × 1080 pixels). This resolution has enough details if later analysis has to be done. The frame rate was 30 fps which is also adequate for recording traffic events in cities. The camera was set for cyclic recording, which means the monitored period was automatically split into 5 minute parts. This enabled easier processing hence the handling of the videos doesn't require extreme memory in the computers. The storage format was mp4 without sound recording. A 5-minute part with these settings was about 560 MB. The camera was equipped with 64 GB microSD card for storing the videos.

The first processing step was the format conversion from mp4 into avi because of the image processing environment. The evaluation of the videos was in MathWorks Matlab supported several codecs, but not the same having actually in the action camera. The conversion has kept all essential parameters (resolution, frame rate, image quality). To ease the video processing on an average laptop, the resolution was decreased to 360p format, meaning an image size of 360×640 pixels.

The processing algorithm is the following. The first 50 frames of the recorded video footage were used to create a reference. The reference is a base, which has mostly the background, the lanes, the trees, the non-moving vehicles and all “irrelevant” image content. The important part of the image is the foreground aimed to contain only vehicles. Then the coming frames were compared to the reference to extract the difference, in this case the vehicles. All so detected vehicles are in form of a binary blob, where the center or the boundary box are easily to calculate. These features enable to represent the vehicles in a simple way, then passing a cross section has to be registered. The registration times can be used to compute the follow-up times for a sophisticated traffic analysis.

4 Data

We chose two locations to collect data for our research. In both locations the traffic operational conditions were ideal for the analysis of queue dissipation dynamics: the queues can discharge freely, no turning movements or side streets to influence the operation, frequent congestions and no heavy trucks or buses. The first location, Egér road is a busy commuter route on the verge of the western part of Budapest. The involved four-lane road section plays an important role in the suburban road transport, in the analyzed direction the traffic is heavily congested in the morning peak hours. The cycle length of the intersection is 120 s with 86 s green time for the analyzed direction. Figure 1 shows the layout of the location.

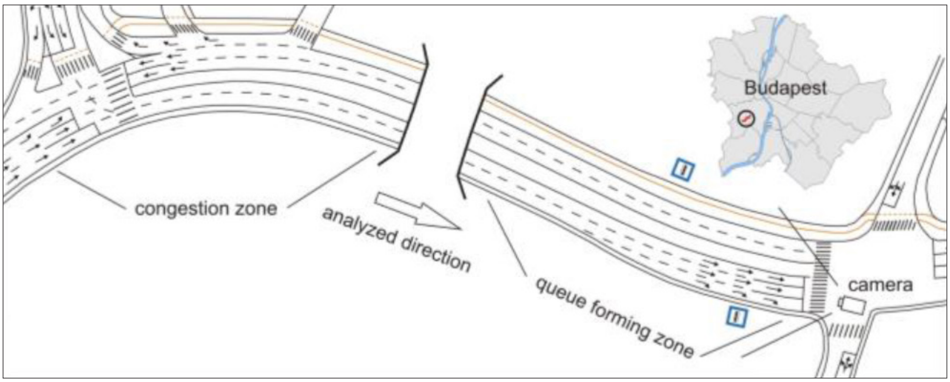

Figure 1 Location 1: Egér út, Budapest

The second and third locations were the lower quay on Buda side, which is an all day busy urban transport artery across the heart of Budapest (Figure 2). The involved two-lane road section plays an important role in the long-distance urban road transport and the city logistic. Two traffic direction were examined as it shown in Figure 2. The first one goes straight to north, this is the main direction, the second one ingress the main stream in the analyzed intersection. Both analyzed directions are heavily congested in the morning peak hours. The speed limit is 50 km/h, the cycle length is 90 sec. The main direction has 51 sec green time, the minor stream has 35 sec. 40 cycles of data were conducted in the morning peak hours in the intersection.
The fourth and fifth measure spots located in the same intersection (Figure 3). The two-lane road links the high prestige residential zone of Buda hill and the city center. We analyzed two directions in the intersection. Figure 3 shows the layout of the location and the examined directions. The first direction goes straight to the city center, the second direction turns left. Both analyzed directions are congested in the morning peak hours, the congestions in the left turning stream are more excessive. The speed limit is 50 km/h, the cycle length of the intersection is 90 sec. The first direction has 50 sec green time, the second direction has 20 sec.

The data collections were conducted in the morning peak hours. We collected 6-13 cycles of data for the analysed traffic flows, depending on the cycle time of signalization.

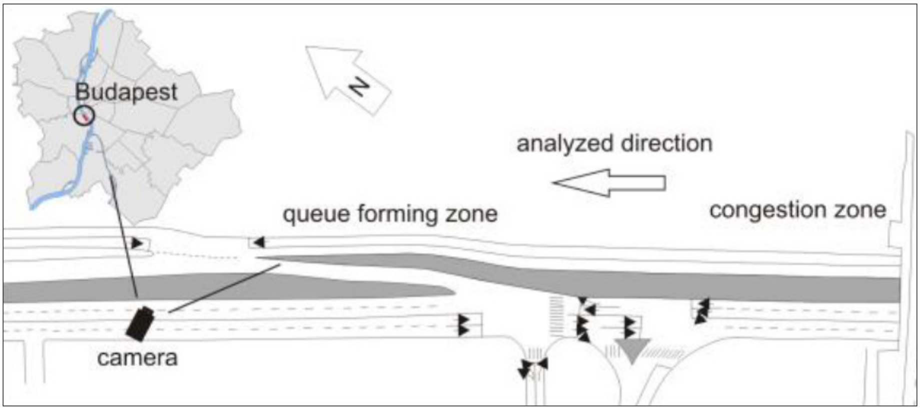

Figure 2 Location 2: Műegyetem rakpart, Budapest

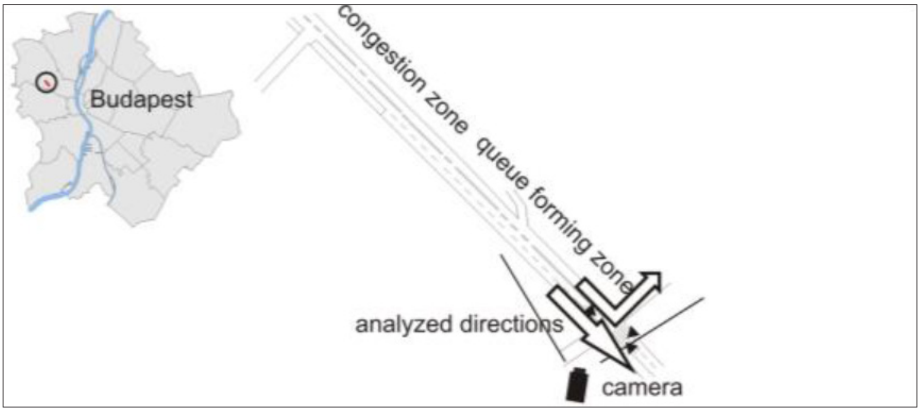

Figure 3 Location 3: Hűvösvölgyi út út, Budapest

5 Data analysis

The headway data are presented graphically in Figure 4-6. The results do not justify any of the three assumptions mentioned in the literature: the headway values are not constant, not compressing nor get longer. According to our findings the lanes of two-lane directions are used in an unbalanced way. This is due to the continuous lane changing to overtake the slower vehicles, so the left lane has significantly lower values than the right one. Another case of interest is the smaller headway values in the left turning lane. Again the difference is significant, this phenomenon originates from the lower speeds of turning movements. The variance analysis did not show any other significant difference due to location or lane configuration. However the analysis of queue positions shows a very interesting repeating pattern. The headway values characteristically decreasing to the seventh-ninth position, and there comes a significant raise of headway values, which descends back to the lower levels from the thirteenth-sixteenth position. At the end of the green time aggressive tailgating can be observed, which results significantly lower headway values everywhere.

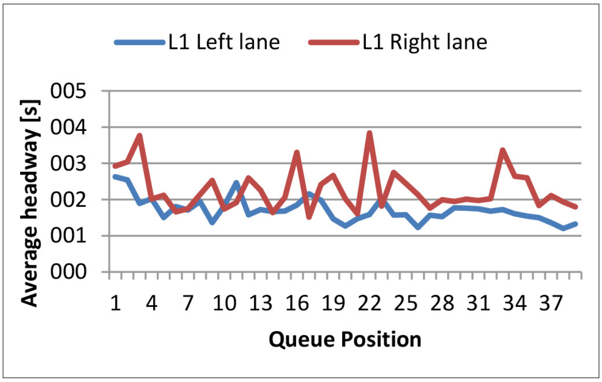

Figure 4 Average headway by queue position at Egér út (Location 1)

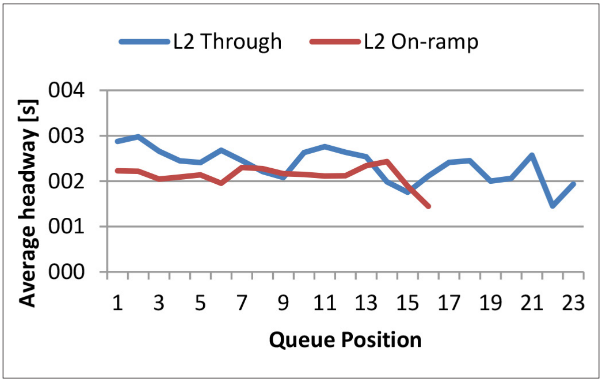

Figure 5 Average headway by queue position at Rakpart (Location 2)

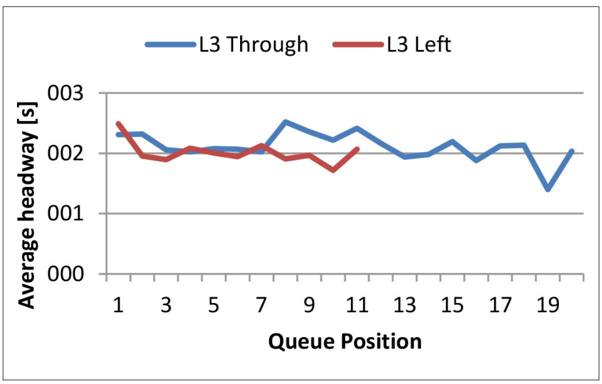

Figure 6 Average headway by queue position at Hűvösvölgyi út (Location 3)

Analysis of variance test was conducted using SPSS to determine the significance of the location, position and lane configuration. The results showed that position (sig value 0.056) and position (0.132) do not influenced headway significantly, but lane configuration (0.000) does a significant effect. However the r-squared value for this three factors is 0.239, so there are other influencing factors in the background.

6 Conclusions

The headway characteristics of dissipating queues were examined in Budapest, Hungary. The discharge headways did not demonstrate a constant, a compressing or an elongation trend. The data showed a regular pattern, compressing at the beginning of the queue, elongation in the middle, then compressing again. This indicates that by managing queue length at signalized intersections the delays might be decreased. The location parameters did not explain the variance in the data. The lane configuration has a significant effect on the headway in dissipating queues, so it should be taken into account in further analysis. The analyzed parameters explain only 24% of the total variance. Further research should explore these traffic parameters.

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