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主　論　文　の　要　旨

論文題目　A Study on Modeling Downstream Influence in Signal Controlled Arterials
（信号制御された幹線道路における下流影響モデリングに関する研究）

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論　文　内　容　の　要　旨

Signalized arterial is the core traffic facility of the urban road network and its performance is directly related to citizens' commuting convenience. The signalized intersection is one of the key components of signalized arterials. Their operations considerably affect the performance of the whole road system. Spillback describes the situations that downstream queues extended over upstream stoplines so that upstream platoons cannot be discharged normally. It is a common traffic issue on signalized arterials when traffic is extremely congested. However, even before spillbacks, the capacity of each intersection can be influenced especially on the signalized arterial on which intersections are closely spaced and undertake high input volume. This effect is called the downstream influence which is a visual and psychological impact on upstream drivers. While waiting to be discharged in an approach, drivers observe the size of the downstream queue and estimate the duration of the downstream queue. Base on this, then they will know whether their forward routes can be interfered by downstream traffic. If they noticed that their desired driving speed cannot be achieved, they may sacrifice the efficiency to pursue safety and comfort. As a result, the performance of the discharge flow is discounted. Meanwhile, this impact can be propagated and amplified towards the upstream direction. This is the reason why, in peak time, congestions occurred in upstream sections of designed bottlenecks.

However, in current practice, existing traffic simulators cannot capture this phenomenon properly, because they ignore the capacity drop before spillback happens. Meanwhile, estimation methodologies in existing manuals do not include factors comprehensively explaining the downstream influence. Correspondingly, the primary objective of this research is to <u>theoretically model the downstream influence and propose a procedure that can properly estimate the influenced saturation flow rate (SFR, hereinafter) and start-up lost time (SLT, hereinafter)</u>. Several questions should be answered before achieving this target. How to measure and quantify the downstream influence? How to introduce the downstream influence into the traffic simulation on signalized arterials? More importantly, how to produce estimation methodologies for SFR and SLT that can be applied in practice? However, fundamental research regarding the above questions is very rare so far. Moreover, empirical cases of discharged flow with downstream influence are important and not easy to be observed. Finding proper survey sites is another challenge of this study. To solve the above questions, the effort of each chapter is highlighted below.

As an initial step of this research, fundamental philosophies of the discharge process at signalized intersections are introduced in ***Chapter 2***. Also, attention is also given to reviewing literature about related researches. Existing methodologies about SFR and SLT estimations are listed and compared. Also, previous researches about downstream influence are summarized, which aims to provide a deep understanding of current research gaps and pave the way for this research.

Chapter 3 quantifies impacts of the downstream traffic on the discharge flow at upstream through lane by both empirical study and theoretical model. Utilizing the data collected at an experimental site of Yasukuni-tori in Tokyo City, SLTs and SFRs of 5 approaches at 3 signalized intersections are statistically studied with several downstream factors (queue length, segment length, and offset). Results show that long queues in the short downstream segment under large positive offset may lead to low SFR and large SLT. Based on these findings, a virtual speed (v_{op}) is created to measure the downstream influence, v_{op} is the speed by which the upstream platoon joins the downstream queue just at the time when the last vehicle starts to move. v_{op} is a function of queue length, segment length, and offset. By using this variable as the core indicator, the intelligent driver model (IDM) is improved and the new model is named as IDM+ in this study. A micro-simulation platform is designed based on the IDM+. Moreover, simulated trends are generalized and summarized into a two-step model by doing the regression analysis on data that were produced from the simulation experiment. In this two-step model, v_{op} is firstly calculated based on downstream factors. Influenced SFR and SLT are then derived based on the v_{op}. Firstly, the new model completely coincides with the experiment data. More importantly, it shows a similar trend and has a good fit with what was observed from the survey site.

Chapter 4 analyzes the downstream influence on signalized arterials. The cell transmission model (CTM) is a popular model of simulating traffic propagations and modified CTM improved the basic theory so that it can simulate realistic discharge features (SFR and SLT). In this study, downstream impacts are introduced into the modified CTM letting its parameters be governed by models of influenced SFR and SLT (from *Chapter 3*). Firstly, the performance of the proposed CTM is proved to have equivalent performances as the IDM+. In order to further test the new CTM, a CTM based platform is created for simulating a real-world arterial, the Hirokoji-tori in Nagoya. The comparison result shows that the modified CTM model considering downstream influence fits the observed traffic flow on signalized arterials better than the existing CTM. Especially in predicting the traffic congestion, the newly proposed CTM has a very outstanding performance. This conclusion emphasized the important role of downstream influence in modeling traffic propagation along signalized arterials. Finally, the proposed model is tested through a sensitivity analysis by which it is pointed out that high traffic demand, high entry flow from the minor streets, short segment links, large positive values of both downstream and secondary downstream intersections' offsets may result in the upstream congestion of signalized corridors.

Chapter 5 mainly proposes a methodology that can estimate adjustment factors for SFR and SLT by the long-term traffic demand profile instead of the real-time queue length data. In the beginning, another CTM based platform is created by use proposed CTM to simulate the discharge process at a signalized intersection. By utilizing the data from simulations, the relationship between traffic demand and queue length is modeled by the regression analysis. Following the hint of models of influenced SLT and SFR in *Chapter 3*, the estimation model for adjustment factors is structured into a two-step model as well. Firstly, v_{op} is calculated by the estimated queue length along with other downstream factors. Secondly, another regression analysis is done to determine the relationship model between simulated adjustment factors and newly calculated v_{op}. Then, CTM based platform and the proposed estimation procedure are performed for 6 specially designed scenarios. Results are shown in contour line figures. They revealed that lower green ratio, smaller cycle length, and more flow from minor streets result in more serious downstream impacts. Finally, the proposed estimation procedure is further applied in real-world approaches comparing with the methodology prescribed in MTSCJ. Results indicate that proposed adjustment factors are reasonable and necessary to be included in practice.

Chapter 6 highlights the major findings of this research. Consideration of multi-lane Arterials, the stochastic features of calibrated parameters in the car-following model, clearing vehicles influence, clearance lost time, and autonomous vehicle flow are suggested as significant future study points in order to reach the final goal of dynamic network traffic control considering downstream influence.