A DEVELOPMENT OF EVALUATION METHOD FOR ROAD TRAFFIC PERFORMANCE

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Abstract : Traffic volume, speed, and travel time are typically used for evaluating the effects of road traffic systems by applying before and after measures of effectiveness. A conventional method is to make a simple comparison for the changes of these measures. However, this method has limitation in reflecting the system-wise changes in urban roadway networks. To overcome this, a method that employs the level of service (speed) variation and traffic volume (throughput) variation made in time-space plane is presented. In addition, this paper presents a method to evaluate overall performance of road traffic by combining the level of service and traffic volume variations. This method provides analysts for the time period maintaining a level of service interested as well as total traffic volume passed during the same time period at the level of service. This paper presents some empirical results collected from the field in Seoul.

Key Words : Effectiveness, Performance, Level of Service, Throughput, Variation

1. GENERAL

System evaluation is one of the primary functions of a traffic control system. Evaluation assesses performance level of the operations and maintenance function. In order to ensure that the system still meets overall needs, many agencies want to make a more in-depth evaluation of system and maintenance periodically rather than to make short-term evaluations which assess the immediate effects of an operational strategy and timing change.

Travel volume, travel speed, and travel time are typically used for evaluating the effects of new systems on traffic flow quality, control strategies, and other operational improvements by applying before and after measures of effectiveness (MOEs). Using these measures, in order to assess the effects, we have traditionally made a simple comparison for the changes of the measures. However, this method has limitation in reflecting the system-wise changes in traffic control, congestion level and travel patterns in urban area. In other words, this method is not able to describe dynamic effects of system's performance such as the traffic changes in time and space plane. The main reason for this is that if there are some changes in road traffic system, drivers' behaviors and travel patterns will be changed in terms of trip departure time and congestion level, so the simple comparison of the before and after measures may not be reasonable.

This paper is an attempt to improve conventional technique for evaluating the road traffic performance. To do so, this paper presents new technique that employs time-space speed (or level of service) variation and time-space traffic volume variation, where the speed is average speed and traffic volume is throughput measured during a given time period (*e.g.*, every 5 to 15 minutes). Using the two variations, it is undoubtedly easy to figure out traffic flow quality or level of service, bottleneck locations, congestion time period, congestion boundary, and the roadway capacities (service rates at signalized intersections).

In addition to the variations, this paper presents a new method for evaluating overall performances of road traffic, which has been developed by combining the key outputs of the level of service and throughput variations. A remarkable advantage of this method is that analysts can measure the time period maintaining a specific level of service as well as the total traffic volume passing the roadway section during the some time period at the some level of service. In this paper, all the new evaluation methods are explained by using the real data obtained from a major arterial in Seoul.

2. DESCRIPTION OF EMPIRICAL DATA USED

In practice, for the purpose of evaluating road traffic performance, it should be necessary to compare the changes in travel speed and traffic volume simultaneously and the variation of level of service. A single comparison of travel speed or traffic volume made independently may mislead analysts. The two traffic variables (*i.e.*, speed and volume) are interacted, so the changes of these variables should be assessed simultaneously in the time-space plane. To do so, the speed and traffic volume should be collected during the same time period

2.1 Speed Data

In order to evaluate road system's performance in urban roadway network, average travel speed of each roadway section is more appropriate for the purpose than spot speed. In this study, the average speed data were collected by floating car method every 5 minute interval. For the data accuracy, more than 3 passenger cars were assigned to each time interval.

The study site is a 2.5km long section of a major arterial that links between the western region of Seoul and the old downtown area. The study site is consisted of 6 to 8-lane sections and located near the old downtown. The speed limit of the study site is 60km/h. Figure 1 is the layout of the study site and Table 1 summarizes some characteristics of the study site.

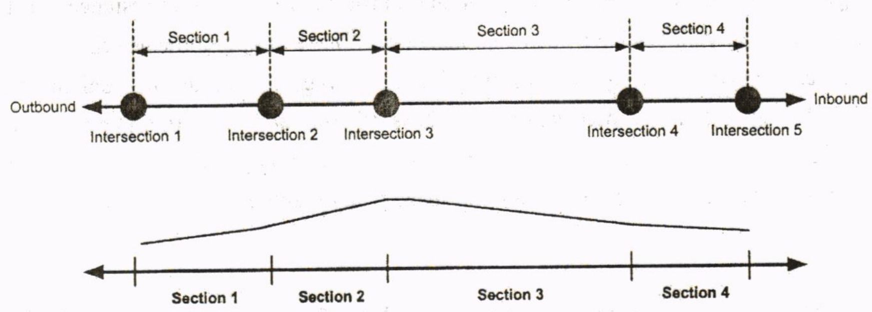


Figure 1. Layout of study site

Table 1. Some characteristics of the study site

	Section 1	*Section 2*	*Section 3*	*Section 4*
Distance (m)	560	280	950	340
Grade (%)	+1	+2	-2	-0.5
Total Number of Lanes (Each Direction)	4 lanes	4 lanes	4 lanes	4 lanes
Exclusive Bus Lane (1 Lane for Each Direction)	Operation	Operation	Operation	N/A

2.2 Traffic Volume Data

Signal cycle time and phases are often changed for improving the average service rate or capacity and reducing the average delay at an intersection. The number of lanes as well as lane width may be also changed for the same purpose. If signal phase and green time for a specific approach have been changed, traffic volumes of all the relevant approaches may be improved, while those of other approaches may not be improved. In such case, a simple comparison of traffic volume and delay of each approach at the intersection is not able to represent the overall improvement efforts reasonably.

At a signalized intersection in the study site, for an example, signal phase for left turning vehicles was not provided to reduce signal phases and increase green time for through traffic (refer to Table 2). As a result, traffic volumes for through and right turning movements were increased due to the fact that left turn vehicles had to change their approaches. In this case, it seems hard to say that those movements have been improved, since their travel speed would be changed due to the increase of traffic volume. Furthermore, the travel distance and travel time of the left turn vehicles have been also increased. This example indicates that in order to reflect the changes of signal operation it may be reasonable to count all the vehicles passing upstream of stop line at an intersection regardless of approaches. In this paper, the traffic count is defined as throughput. Throughput data were manually collected every 5 minute interval during the same time period when the speed data obtained.

Table 2. An example for signal operation and its effects on traffic movements.

Signal Phases and Traffic Volumes		
Cycle Time (sec) / Phase	Before	After
	140	90
Φ 1	250 2150 2000 350	250 2150 2000 350
Φ 2	300 400	230 1800 1750 150
Φ 3	180 1700 1600 100	N/A
Φ 4	200 150	N/A

It is noteworthy that if we draw cumulative throughput diagram as shown in Figure 2, we can easily estimate the average service rate and congestion time period without additional field survey and intensive analyses. The data in the figure were collected during the morning peak period between 7 a.m. and 8 a.m. at a signalized intersection in the study site. In the figure, the maximum slope of straight line connected cumulative throughput data points can be explained as the average service flow rate or capacity for the relevant approach at the signalized intersection. During the previous time period between 7:10 and 7:40, the slope of cumulative throughput curve is extremely low, which means the intersection has been congested during that time period. The congestion time period was reduced and service flow rate was increased. This interpretation is not a new and surprised, but it implies that the cumulative throughput diagram has fruitful information about the system's performance. In summary, it is very easy to create this diagram, so this method can be used as an analysis tool for several practical purposes in traffic engineering.

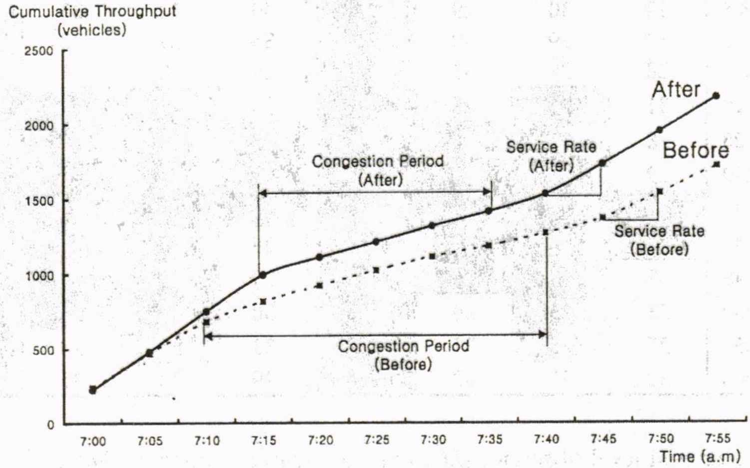


Figure 2. A cumulative throughput diagram and its some important implications.

3. EVALUATION METHOD FOR DYNAMIC EFFECTS

3.1 Level of Service (or Speed) Variation in Time-Space Plane

Table 3 shows an example for speed variation made in time-space plane. The numbers in the figure indicate the average speed of vehicles traveled each roadway section for every 5 minute interval. In the table, the two traffic flow patterns of before and after study time periods are very similar and clear, so it is not hard to know whether the road traffic performance is improved or not. If the traffic patterns of before and after study time periods are not similar and not clear, we should be careful for assessing the effectiveness of the traffic system implementations. To do so, it would be a good idea to check the variation of level of service instead of speed in time-space plane made by the same manner as the speed variation.

At the same level of service, speed change will not be a big problem. In other words, although the average speed of a roadway section was decreased, it would be hard to say that the system's performance was not improved because that the same level of service has been maintained. Thus, we should do further check for traffic volume change. The significance of comparison the speed with traffic volume changes has been mentioned already in Chapter 2.

Table 3. Speed variation in time-space plane.

Time (a.m)	*Before*				*After*			
	Section 1	*Section 2*	*Section 3*	*Section 4*	*Section 1*	*Section 2*	*Section 3*	*Section 4*
7:00~7:05	28	30	29	26	40	32	33	26
7:05~7:10	30	29	30	25	35	29	30	25
7:10~7:15	28	28	33	23	29	28	31	24
7:15~7:20	31	26	28	20	30	23	24	22
7:20~7:25	28	23	26	19	26	[illegible]	21	20
7:25~7:30	29	19	20	16	[illegible]	18	20	19
7:30~7:35	20	18	15	14	[illegible]	20	15	17
7:35~7:40	22	17	18	13	28	[illegible]	19	18
7:40~7:45	32	23	25	15	29	23	25	20
7:45~7:50	33	25	30	20	30	25	26	21
7:50~7:55	27	26	31	[illegible]	33	26	28	23
7:55~8:00	30	35	32	23	29	28	35	25

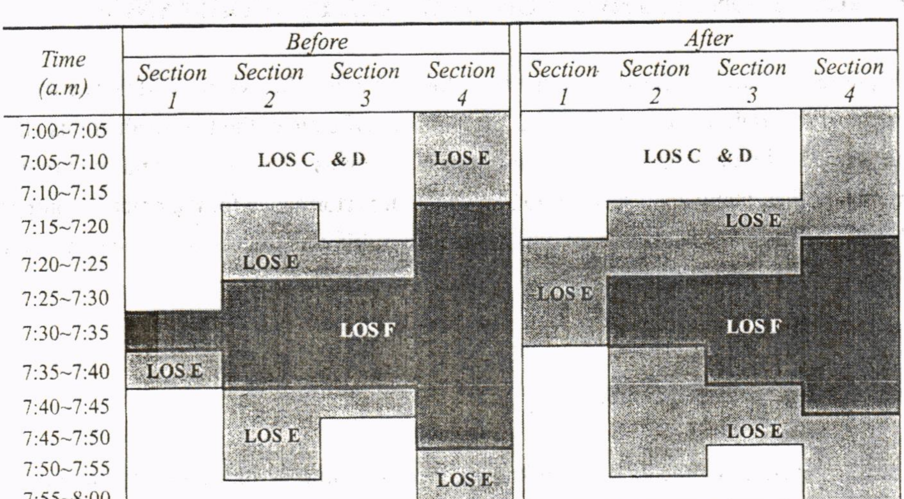
According to arterial level of service (*LOS*) in US *Highway Capacity Manual* (refer to Table 4), the study site is divided into three regions as *LOS* E, *LOS* F, and other LOSs. Table 5 is the level of service variation. This table has the same meaning as Table 3, but represents the speed variation in a very simple pattern rather than Table 3. The boundary of *LOS* E and *LOS* F regions in the study site is represented as the dark lane. *LOS* F region is reduced, while *LOS* E region is slightly increased. The congestion time periods at sections 1, 2, and 4 are reduced. Overall traffic conditions of the study site have been obviously improved in terms of traffic flow quality.

The level of service variation can provide analysts for much useful information about the movement of congestion boundary over time and space. A remarkable advantage of this method is that we can easily figure out the time period maintaining a specific level of service (*e. g., LOS* F) as well as the roadway section experienced the same level of service. If we want to do macroscopic evaluation for a roadway section during a specific period (*e.g.*, morning and evening peak periods), the variation of level of service can be obtained by using the average travel speeds measured during the same period. For analysts, it would be much convenient than Tables 3 and 5. We are not still sure whether the service rate of the site is also improved, so we have to dive into the next step for checking the traffic volume changes.

Table 4. Level of service for Arterial (US HCM)

Arterial Levels of Service				
	Arterial Classification			
	I	II	III	IV
Range of free-flow speeds (km/h)	72 to 89	56 to 72	48 to 56	25 to 35
Typical free-flow speeds (km/h)	80	64	53	30
Level of Service	Average Travel Speed (km/h)			
A	≥ 68	≥ 56	≥ 48	≥ 40
B	≥ 55	≥ 45	≥ 39	≥ 31
C	≥ 43	≥ 35	≥ 29	≥ 21
D	≥ 34	≥ 27	≥ 23	≥ 14
E	≥ 26	≥ 21	≥ 16	≥ 11
F	< 26	< 21	< 16	< 11

Table 5. Level of service variation in time-space plane.



3.2 Traffic Volume Variation in Time-Space Plane

Table 6 shows the traffic volume variation in time and space plane. In the table, the dark cells are relevant to *LOS* E and F shown in Tables 3 and 5. The traffic volume pattern is generally matched with the expectation where speed decreases as traffic volume increases. The bottleneck is likely to be in section 4 and the queue occurring at there propagates up to upstream Section 1. The congested region has been clearly reduced.

Table 6. Traffic volume variation in time-space plane

Time (a.m)	*Before*				*After*			
	Section 1	*Section 2*	*Section 3*	*Section 4*	*Section 1*	*Section 2*	*Section 3*	*Section 4*
7:00~7:05	149	156	163	241	147	160	154	224
7:05~7:10	135	142	156	227	128	141	147	256
7:10~7:15	142	135	142	213	147	122	128	269
7:15~7:20	149	199	149	**134**	141	198	205	244
7:20~7:25	142	206	213	**106**	192	211	218	**115**
7:25~7:30	135	**114**	**114**	**99**	230	**115**	**128**	**102**
7:30~7:35	**107**	**85**	**85**	**92**	[illegible]	**128**	**96**	**108**
7:35~7:40	213	**121**	**99**	**71**	179	192	**122**	**96**
7:40~7:45	142	220	178	**85**	141	211	218	**115**
7:45~7:50	149	206	121	**99**	147	224	205	198
7:50~7:55	142	178	114	170	141	218	179	218
7:55~8:00	135	149	135	177	134	179	211	224

4. EVALUATION METHOD FOR OVERALL PERFORMANCE

In Chapter 3, we have discussed two methods for evaluating the system's performance from an aspect of dynamic effects in time and space plane. Of course, the two evaluations should be performed simultaneously, since two traffic variables (*i.e.*, speed and volume) are interacted. In fact, many analysts want to know overall performance for the practical purposes, so this is the primary objective of this paper. To fulfil this objective, a new method is proposed.

4.1 Key Concept of New Method

It is most interested for the analysts to know congestion time period, traffic volume passed, and travel speed or level of service. New method has been designed to produce these results simultaneously by combining level of service and traffic volume variations. To do this, a table for level of service of a roadway section is created based on average speed data collected a specific time period (*e.g.*, 5 or 10 minutes) by the same manner described in Chapter 3. Then, time periods and traffic volumes for each level of service maintained are summed up. If the table is completed, the analysts can measure the time period maintaining a level of service interested as well as the total traffic volume passing the roadway section during the time period at the same level of service.

4.2 An Empirical Example

Table 7 summarizes the results for Section 4 in the study site obtained by the method above-mentioned. Total travel times and total traffic volumes of each level of service can be estimated from the results in Tables 5 and 6. Congestion (*i. e.*, *LOS* F) time period was reduced and time period of *LOS* E was increased. This implies that the roadway section was operated very effectively at the capacity level. Total traffic volume was 7,032 vehicles/hour during the morning peak period from 7 a.m. to 8 a.m. previously, but the volume was increased about 17.4% after. Table 7 is very simple, but its implication is much fruitful for the analysts. It should be reminded here that in order to complete this table we have to prepare Tables 3, 5, and 6. If the analysts want to do macroscopic evaluation for a roadway section during morning and evening periods, Table 7 can be obtained by using the average speed measured during the same period.

Table 7. Total time period and total traffic volume of level of service

	Total Time Period (minutes)		*Total Traffic Volume (vehicles)*	
	Before	After	Before	After
LOS C & D	105	90	2,982	2,726
LOS E	65	100	2,640	4,366
LOS F	70	50	1,410	1,125

5. CONCLUDING REMARKS

This paper presents several methods for evaluating the effects of road traffic system on traffic flow quality, control strategies, and other operational improvements. The methods are able to assess the dynamic changes of the system's performances by analyzing level of service and traffic volume variations in time and space plane. A method for evaluating overall effectiveness of the system is also presented. Although all the methods proposed have been validated using the real data collected from the field in Seoul, the validation is not enough to confirm the methods' reliability yet, so further empirical studies are requited. However, the results emanating from this paper are very promising and thus, the theoretical concept proposed may be useful for the analysts.

6. ACKNOWLEDGEMENTS

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