ASSESSING DRIVEWAY IMPACT USING MICROSCOPIC SIMULATION MODELS

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abstract:

One of the primary tools for assuring mobility on arterial and thus managing congestion is thought to be access management. But there is little quantitative information on the effect of some basic traffic engineering measures on arterial performance.
The number, location, activity, and design of driveway are perhaps some of the highest priority pending questions related to access management. While there have been some studies, a decisive resolution of the effect of driveway is elusive because it is virtually impossible to run a controlled experiment in the field.
This research addresses the effects of unsignalized driveways on arterial through traffic by means of simulation. Specially, arterial speed-reduction models for through traffic due to driveway impact are constructed, and important underlying trends are identified.

1. INTRODUCTION

In the 1990 Intermodal Surface Transportation Efficiency Act (ISTEA) passed by the U.S. Congress, each state in the U.S. was required to establish six management systems, one of which relates directly to this work --- the congestion management system. Tools such as good access management take on even greater importance in CMS to preserve mobility, and an important issue is how to quantify mobility and how to assess impacts on it. In 1994, in order to maintain the integrity fo road system and lessen traffic congestion problems, the Korea Ministry of Construction and Transport (MOCT) initiated a research project titled 'Development of Access Management Code for Public roads.' Korea research team decided to adopt basic frameworks from DOTs in U.S. and retouched many of its contents considering Korea's legal, institutional, socio-ecomonic and geographical structure that are different from the USA's. While working on the development of the Code, research team has faced, with regard to the implementation of the Access Management Code developed, numerous issues that are still not solved.

In this context this study was motivated by the need to provide a quantitative basis for some traffic policy considerations. Specifically, the question of driveways and their impact needed to be addressed, but the quantitative tools were not sufficient. Based on an extensive consideration of the literature, consultation with experts in the field, and awareness of evolving issues, the direction of study was set: the measure finally selected was average travel speed of through traffic only. Much of the effort was devoted to modifying an existing well-established tool(namely, TRAF/NETSIM) to extract this measure, and to using that tool to investigate some of the highest-priority pending questions related to access management.

2. METHODOLOGY

2.1 Advantages of Simulation in Access Management and Capacity

There are some advantages to simulation and other models in access management:

1) Simulation models have the great advantage that they can allow us to change one key feature such as a driveway volume or location while holding all other things invariant. We can actually run the same traffic in different cases, thereby being sure that we are studying only the effect intended;

2) For the most part, the "other models" are traffic assignment models which select the paths by which traffic reaches its destinations. These decisions are made by rules related to minimizing travel times for the various travellers, subject to the rules on turn prohibitions, capacity limits, and such. These "other models" are very good for area effects. The simulation models such as TRAF/NETSIM are generally more detailed in the operational aspects of vehicle interactions;

3) The advantage of the traffic assignment models is that they improve our estimates of re-routings and allow area VMT estimates to be made. The advantage of the simulation model is that it allows a controlled test environment.

The risk in using such models is that while they try to *emulate* the real world, they do not do so perfectly. Therefore, while we can say "in the simulated case, the following happened...", the ultimate test of reality is the real world.

At the same time, a full investigation is very often not feasible in the field, simply because the variability cannot be controlled and/or because of cost. Consider the case at hand: we are interested in the effect of driveways on the average travel speed on an arterial, and wish to consider the number of driveways, their location, and various volumes both on the arterial and at the driveways.

2.2 The Thru Vehicle Measure of Performance

Vehicles which have just entered an arterial can expect a different (and poorer) treatment in the first arterial link, just as they can expect a different (and poorer) treatment in their last arterial link, as they seek to turn off the arterial. Therefore, the measure should reflect only the true "thru" portion of their trip, because it is during this portion of the trip that the arterial is being used for its defined purpose, namely moving thru traffic.

The concept is shown clearly in Figure 1: only the solid portion of the illustrated trips should be counted. Unfortunately, most traffic tools do not concentrate on only these "thru" elements, but report such measures as average speed in the link, average speed by movement, and stopped delay by total or by movement where "movement" refers to the vehicle as it leaves the link. Likewise, most traffic data does not reflect thru traffic as shown in Figure 1, for very good and practical reasons related to feasibility, cost, and lack of need.

The historic TRAF/NETSIM output is in terms of all vehicles, or certain subgroups by type or by movement. For the purposes of this work, it was important to restrict attention to only those vehicles which entered *and* departed a link as a thru vehicle. These are the vehicles which are using the arterial for its defined purpose, namely the movement of thru traffic.

There are two ways to adapt TRAF/NETSIM to this purpose: modify the source code itself, or extract information from the animation file on the individual vehicle trajectories, allowing the speeds of only appropriate portions of the trajectories to be taken into account. The differences are most interesting. As shown in Figure 2, the average travel speed of the thru vehicles even in a very simple case is some 4-5 mph higher than the average travel speed of all vehicles. The implication for access management is clear, because the common questions include how driveways and such affect these arterial thru vehicles.

Another immediate implication is that certain disruptions ---- driveways on the mainline --- can cause the level of service to degrade even faster than previously thought, because the average travel speed of the real thru (non-driveway, non-turning) traffic is very sensitive to these disruptions.

3. EFFECT OF DRIVEWAYS ON ARTERIAL THRU TRAFFIC

Effects of driveways on arterial performance are perhaps the most discussed issues in access management. While there have been some studies, a decisive resolution of the effect of "just one more" driveway is elusive. This work addresses the effects of unsignalized driveways on arterial thru traffic, by means of simulation. This work does *not* address the obvious adverse effects that signalized driveways have on arterial progressions if the driveways are poorly located. This is well known, and it is considered that an obvious step in the review of any driveway is the effect its location will have on the arterial traffic if and when it is ever signalized, immediately or in the future. Experience argues that driveways from any significant commercial or residential development "grow up" to become signalized intersections.

3.1 The Situations Considered

The base conditions for all runs in this study are: four lane arterial with left turn bays, quarter mile signal spacing, 55 mph free flow speed, excellent progressions, no decel lanes for the driveways. The road is not divided, but some cases left turns in/out of the driveways are prohibited. Other cases allow: (1) decel lanes for the right turn into the driveway; (2) accel lanes for the right turn from the driveway; (3) storage bay for the left turns into the driveways, giving the effect of a median opening for that traffic.

In this study, driveways were generally located on the "south" side of the sample arterials, and the eastbound speed was labelled "Speed 1" and the westbound speed was labelled "Speed 2". Further, all driveway volumes are given as the "in" number, with the "out' equal to the "in".

In all cases when lefts in/out of driveways were allowed, it was assumed that 70% of the total driveway volume came from the side of the road on which the driveway was located and returned to that flow, and that the rest came from the other direction. Unless otherwise noted, all runs and replications simulated one hour of traffic. This was found to be quite adequate for the present purposes.

A range of situations are considered:

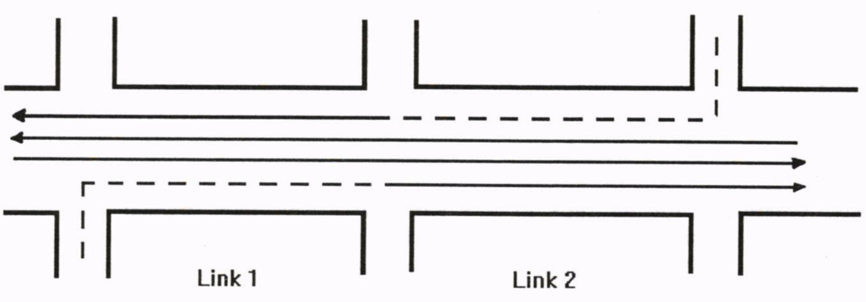
+ the effect of driveway	...........number
	...........volumes
	...........location
+ the effect of driveway	...........right turns only (in/out)
+ the effect of driveway	...........design (accel/decel lanes)

over a set of conditions:

+ arterial flow rates	...........500 to 900 vphpl
+ arterial lanes	...........2 or 3
+ arterial left turn bays	...........yes or no
+ driveway decel lanes	...........yes or no

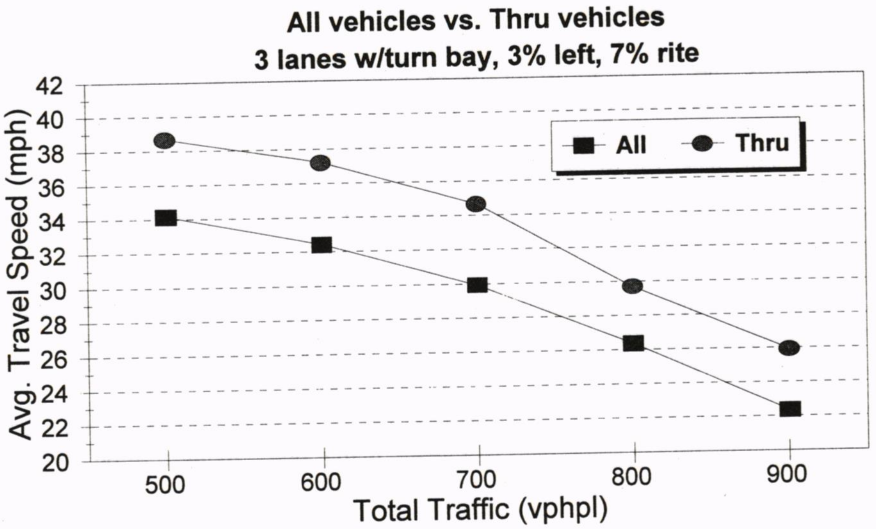
with a default of quarter-mile signal spacings and four links included.

The speeds reported are all average travel speeds of thru vehicles only (defined as above), except as explicitly noted. A total of 1585 different cases were executed, with an average of 9 replications, for a total of 1518 hours of traffic simulated, and outlined in Table 1.



Note: Thru portions shown in solid lines; non-thru portions in dashed lines.

FIGURE 1: IDENTIFYING THE THRU COMPONENT OF ARTERIAL TRIPS



Quarter-mile signal spacing, three lanes in each direction, excellent progression, no driveways, adequate green time, left turn bays, 3% lefts and 7% rights

FIGURE 2 : ILLUSTRATION OF AVERAGE TRAVEL SPEED OF THRU VS. ALL VEHICLES

TABLE 1: SUMMARY OF THE EXPERIMENTAL PLAN FOR STUDY

Topic	Total Runs Used	Runs Not Already Counted
Number of Driveways	55 mph, 6-lanes ; 225	225
	45 mph, 6-lanes ; 60	60
	55 mph, 4-lanes ; 180	180
	45 mph, 4-lanes ; 180	180
Driveway Volume	55 mph, 6-lanes ; 225	0
	55 mph, 4-lanes ; 180	0
Driveway Location	2 driveways ; 72	36
	4 driveways ; 72	36
Dispersed Driveway volume	2 driveways ; 36	16
	6 driveways ; 36	36
	10 driveways ; 36	36
Driveway Spacing	250 ft ; 20*	20
	150 ft ; 20*	20
Effect of Rights Only	RT + LT ; 20	0
	RT Only ; 20*	20
Effect of Accel/Decel Lanes	45 mph, 4-lanes ; 40*	40
	55 mph, 6-lanes ; 180	180
Effect of Accel /Decel/ Median LT Bays	2 egress driveway lanes 55 mph, 6-lanes; 500	500
TOTAL RUNS		1585
TOTAL HOURS OF SIMULATION		1518

* - 20 min. simulation

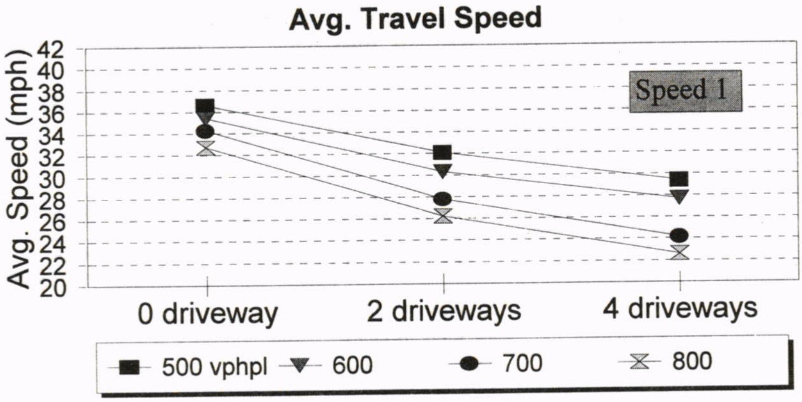
3.2 Number of Driveways

Figure 3 shows the effect of going from none to two to four driveways, each handling 180 vph and all located on the same side of the arterial, spaced 150 feet apart, for the situation depicted in Figure 4. The arterial has two lanes in each direction without deceleration lanes at driveways(four lanes undivided).

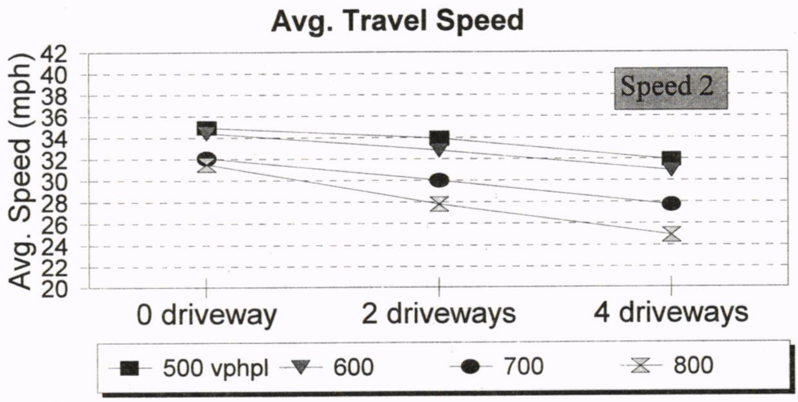
For the volumes investigated, and using 700vphpl as the arterial flow, the effects which stand out are :

> the thru vehicle average travel speed in the eastbound (or same) direction drops by about 6 mph when the first two driveways are added, with the next two driveways causing a smaller impact of another 4 mph;

> the impact on the thru vehicles in the other direction is not as severe, and does not drop as precipitously, being only about 2 mph due to the first two driveways



a) average travel speed eastbound (S1) with 180 vph per driveway



b) average travel speed westbound (S2) with 180 vph per driveway

FIGURE 3 : EFFECT OF NUMBER OF DRIVEWAYS ON ARTERIAL AVERAGE TRAVEL SPEED

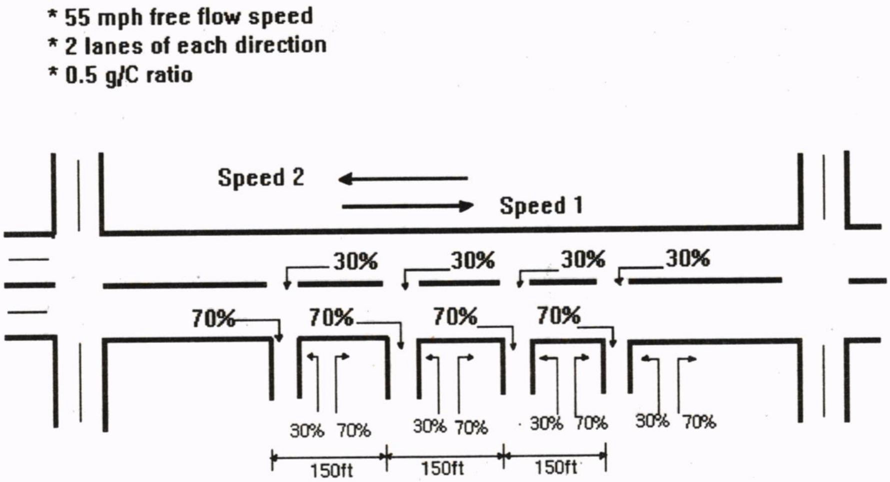


FIGURE 4 : THE DRIVEWAY LOCATIONS ON THE ARTERIAL IN FIGURE 3

3.3 Driveway Volume

Returning to the illustrative case, consider two driveways on the south side of the road, with 700 vphpl along the arterial (both directions). The effect of adding these two driveways on the thru vehicle average travel speed can be summarized as:

DRIVEWAY VOLUME	EASTBOUND THRU VEHICLE AVERAGE SPEED	WESTBOUND THRU VEHICLE AVERAGE SPEED
60 vph	- 2.8 mph	0 mph
120 vph	- 4.1 mph	- 2.0 mph
180 vph	- 6.5 mph	- 2.1 mph

That is, there is considerable effect on the "near" side.

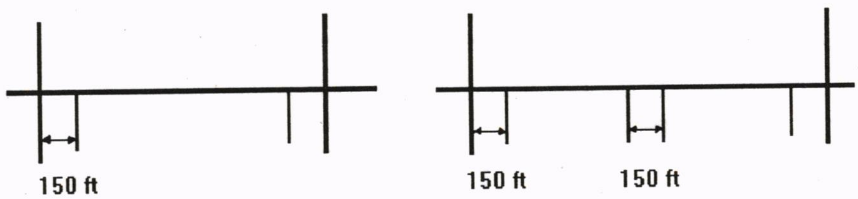
3.4 Driveway Location

The driveways considered above were essentially at mid-block, at a spacing of 150 feet between driveways. The obvious question is, what would have happened if they were closer to the ends of the block?

This was considered for both the "two" and "four" driveway cases, but only two driveways were moved, as illustrated in Figure 5.

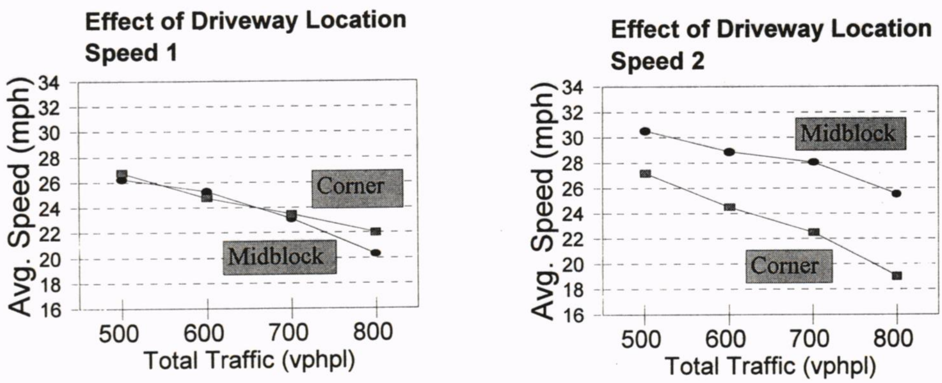
Figure 6 shows a dramatic effect for the case in which there were two driveways and both were moved: the thru vehicle speed on the driveway side did not change much, but the thru vehicle speed on the *other* side dropped by 3-7 mph. Upon reflection, this has much to do with the westbound driveway-bound vehicles interacting with the arterial queue (and intersection discharge) too near the intersection.

Figure 7 shows another aspect of the poor driveway location: the average queue of vehicles trying to leave the driveway is driven up dramatically as the arterial flow increases, but only when the driveway is closer to the intersection. Not only does the arterial become unattractive for the thru traffic, but the driveway traffic itself is clearly adversely affected.



a) two driveways present   b) four driveways present

FIGURE 5 : EFFECT OF DRIVEWAY RELOCATION ON THRU VEHICLE SPEED



a) eastbound vehicles   b) westbound vehicles

FIGURE 6 : SPEED OF THRU VEHICLES, RELOCATING TWO DRIVEWAYS (TWO PRESENT)

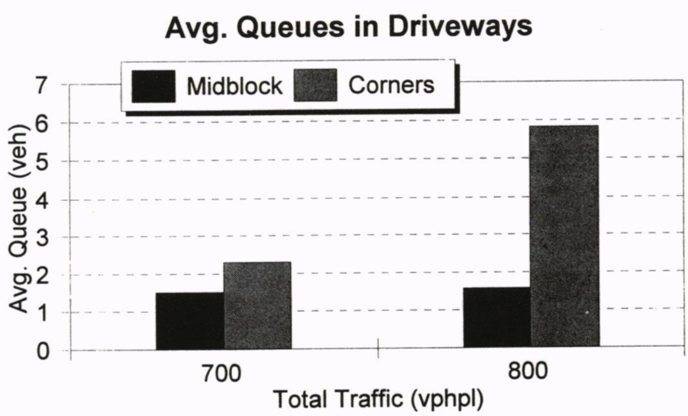
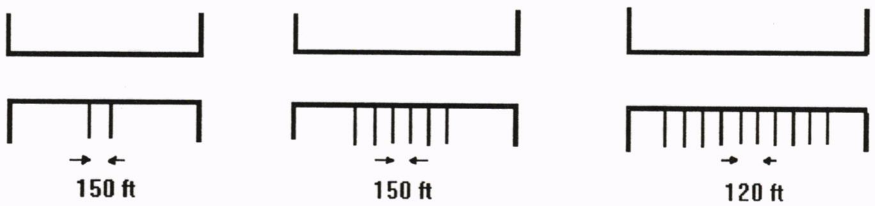


FIGURE 7 : AVERAGE QUEUES IN DRIVEWAYS, FOR DIFFERENT ARTERIAL FLOW RATES

3.5 Dispersed Driveway Volume

Is it better to have several low volume driveways, or fewer higher volume driveways? To consider this, a total driveway volume of 360 vph was considered[1] and allocated amongst two driveways, then six, and then ten. Figure 8 shows the illustration of the different numbers of driveways.



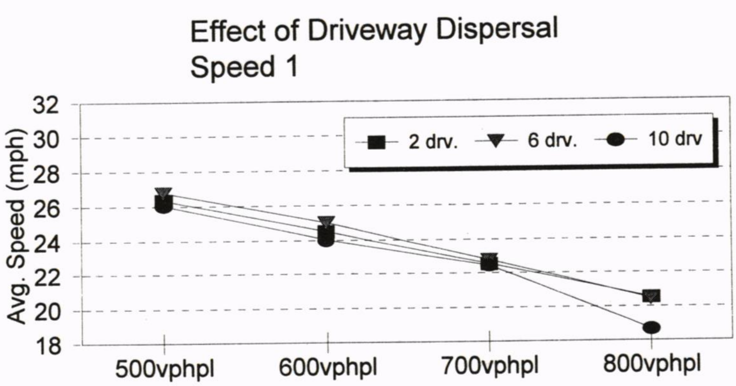
a) two locations b) six locations c) ten locations

FIGURE 8 : DISPERSAL OF DRIVEWAY TRAFFIC ALONG THE ARTERIAL

Figure 9 shows a somewhat unexpected result, in that there is very little difference in the eastbound thru vehicle speed except at highest arterial volume. There is however a noticeable degradation in the westbound direction (the "other" side) which has two elements:

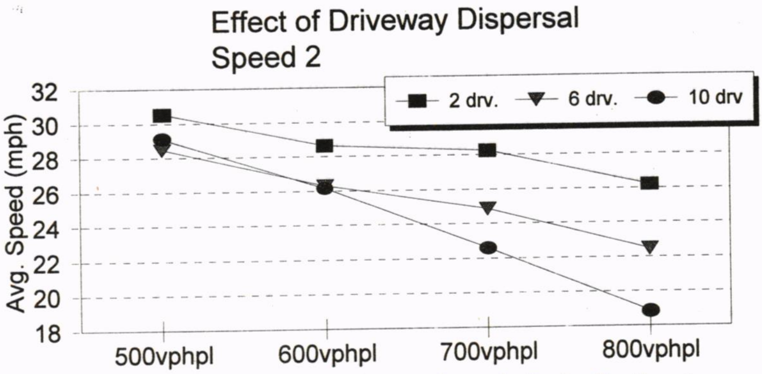
> at lower arterial demand levels, the move from two to six driveways degraded performance, but the move from six to ten did not further degrade performance;

> at higher levels (700 and 800 vphpl), there was degradation from two to six *and* from six to ten driveways ;



a) thru vehicle speed in the eastbound direction

1) This is the "in" number, so that the total in/out is double this figure.



b) thru vehicle speed in the westbound ("other") direction

FIGURE 9 : EFFECT OF DRIVEWAY TRAFFIC DISPERSAL ON THRU VEHICLE SPEED

It appears that several distinct mechanisms are at work. Future work would be needed to finalize an interpretation, but it is likely that: at lower arterial flow rates, the more dispersed turning (six locations, not two) have considerable effect on the left-most lane nominal status as a thru lane; additional driveways do not change this, but then the increasing arterial flow rates degrade the remaining thru lanes; ultimately, at the highest flow rates, the ten driveways may be affecting intersection productivity, just because of their various locations.

3.6 Driveway Spacing

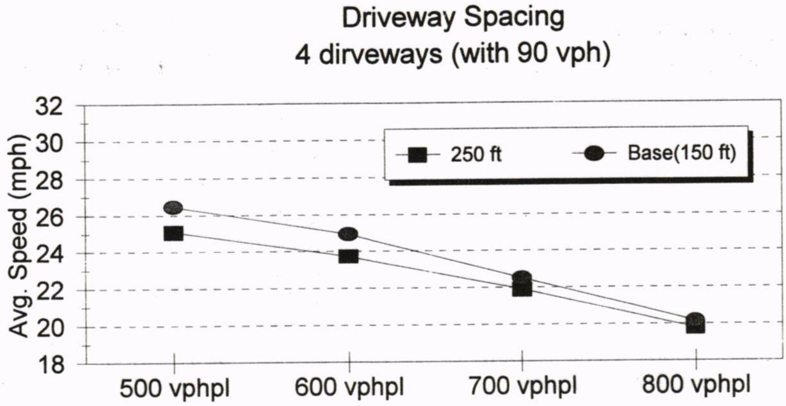
In several illustrations, the driveways were spaced at 150 feet. One minimum practice is to space the driveways at 250 feet. This was considered for a set of runs with four driveways and 90 vph at each driveway.

Figure 10 shows that there is some beneficial effect from the *shorter* driveway spacing, at least in terms of thru traffic in the "other" direction. One must be aware that there are *no* accel/decel lanes associated with the driveways in these cases, due to the dimensions involved. Thus, there is no noticeable change in the "same" direction's thru traffic, at the same time that there is some benefit to the "other' thru traffic if the driveways are closer, and thus closer to the center of the link.

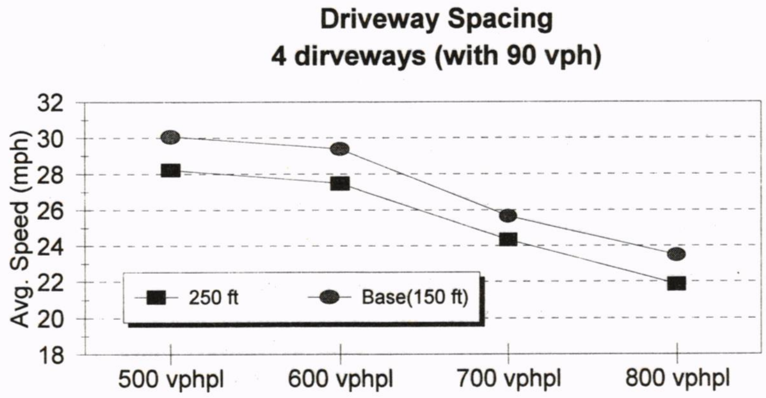
3.7 Effect of Rights Only

Left turns into driveways cause conflicts when they stop in a lane also serving thru traffic, and they degrade the arterial function by affecting the average travel speed of those thru vehicles. They also expose themselves and others to risk because of the speed differences[2].

2) We recognize that left turners stopping or even slowing in a thru lane raise considerable safety issues, but are limited in what can be quantified by the tools available. Thus, we restrict attention to the mobility-related index of arterial average travel speed and do not address the safety issues which we cannot quantify. However, they are real. We also are frustrated that the benefits (or not) of two way left turn lanes cannot be addressed by existing tools.



a) thru vehicle speed in the eastbound direction



b) thru vehicle speed in the westbound ("other") direction

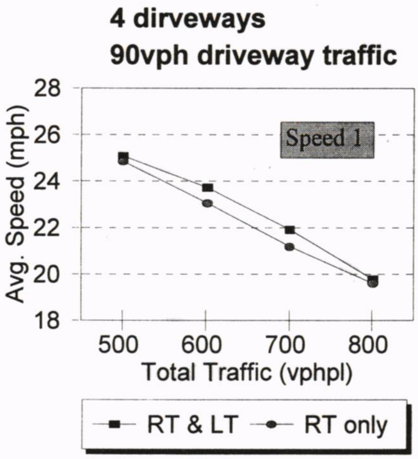
FIGURE 10: DRIVEWAY SPACING FOR FOUR DRIVEWAYS, EACH WITH 90 VPH TRAFFIC

Likewise, left turns out of driveways have risks associated with them, and may also degrade arterial average travel speed.

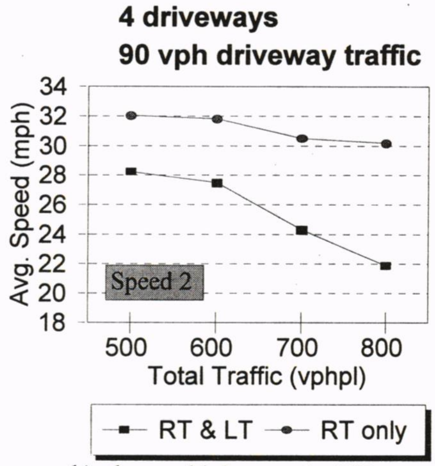
Recognizing that the tools at hand do not address safety and conflict analysis, attention was restricted to the question of the effect on average travel speed.

Figure 11 shows the results for the simple case in which 100% of the driveway traffic arrives by making right turns from the eastbound flow, and exits the driveway by making a right turn to return to that flow.

Clearly, there is benefit to the "other" direction, because none of its vehicles now interfere with its thru traffic. There is also benefit to the eastbound thru traffic by conflicts being reduced. These benefits can be enhanced by driveway design features as simple as accel/decel lanes.



a) thru vehicle speed, EB



b) thru vehicle speed, WB

FIGURE 11: EFFECT OF ALLOWING RIGHT TURNS ONLY IN/OUT OF DRIVEWAYS

3.8 Driveway Accel/Decel Lanes

Figure 12 shows simple accel/decel lanes modeled using NETSIM, just to allow the distinction between "nothing" and "something". Four cases were considered:

X0 = no driveway traffic (for reference)
X1 = driveway traffic, but no decel/accel lanes at the driveway
X2 = driveway traffic, with both decel/accel lanes
X3 = driveway traffic, with decel lane only

The test cases had free flow speed of 55 mph on a 6-lane arterial with 180vph at each driveway, with nine replications of each case.

Figure 13 shows that the presence of the decel lane is quite important, in that it mitigates the effect of the driveway traffic on the near-side thru vehicle travel speed by about 50% over most arterial volumes. The accel lane is not important in its effect on the speed of arterial traffic.

The same figure shows that the decel/accel lanes have no consistent and notable effect on arterial traffic in the "other" direction. That is not to say that the very presence of the driveway does not disrupt that traffic: when there is no driveway (that is, the "X0" case, that traffic operates much better than when there is a driveway, because traffic is obviously making left turns into that driveway and impeding thru movement. However, the decel/accel lanes for the near side (eastbound) traffic does not help the westbound thru traffic.

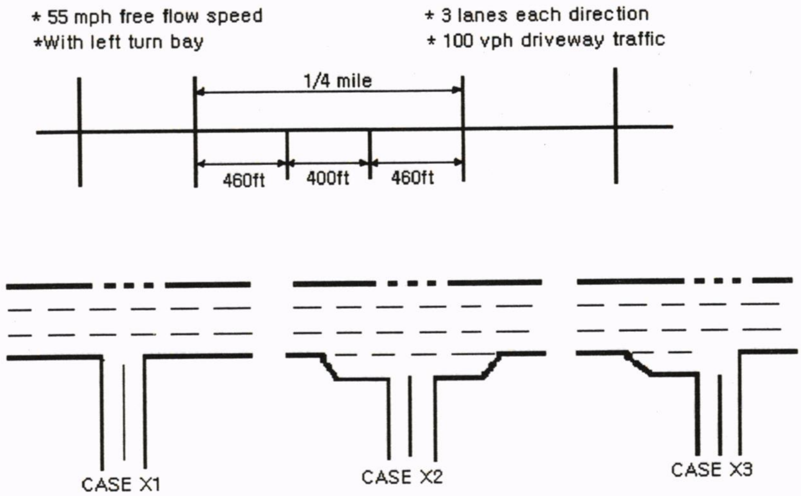
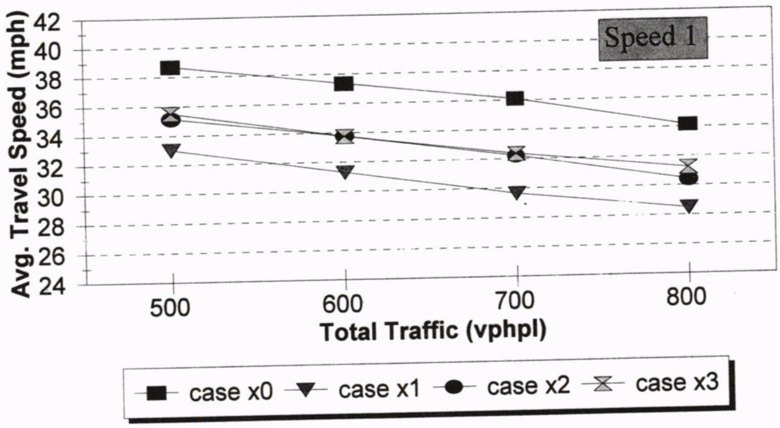
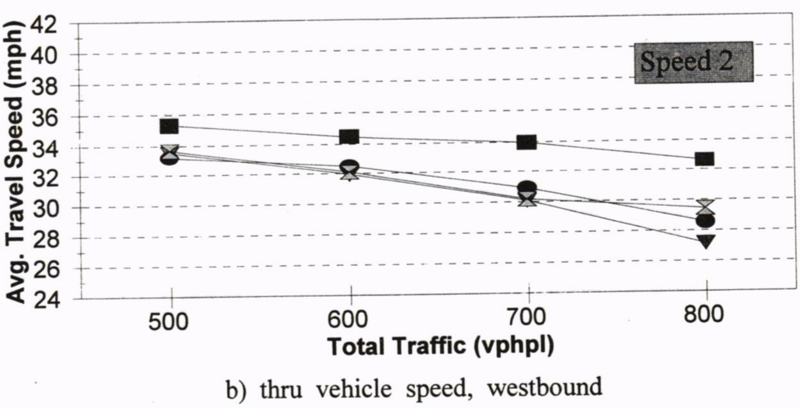


FIGURE 12 : ACCEL/DECEL LANES AT THE DRIVEWAY



a) thru vehicle speed, eastbound



b) thru vehicle speed, westbound

FIGURE 13 : EFFECT OF ACCEL/DECEL LANES, TWO DRIVEWAYS, 180 VPH EACH

One other design feature can also be considered within the structure of the simulation tool being used: Figure 14 shows four cases over the same flow and lane condition as the previous simulation runs for investigating the effect of a median turn bay accommodating the left turners into the driveway:

Z1 = no special features, but driveway traffic present
Z2 = decel lane on eastbound
Z3 = decel/accel lanes on eastbound, median bay for westbound lefts
Z4 = decel lane on eastbound, median bay for westbound lefts

Figure 15-a shows that the decel lane is the primary beneficial feature for the eastbound thru traffic, although the presence of the median opening without the accel lane at the high arterial volume does cause some degradation (see Z4 versus Z3 at 8000 vphpl). The benefits of the median turn bay on the westbound thru traffic are clear in Figure 15-b, where a 3-4 mph improvement is noted at higher volumes when the median turn bay is present.

These analyses can confirm that the decel feature has obvious benefit to the thru vehicles, which one of course would expect, but that the accel feature does not. This is less obvious but plausible: traffic came from the driveway enters the mainline on gap acceptance and lessens the impact on the arterial thru traffic, but less benefit of acceleration lane can be influenced by TRAF/NETSIM design mechanism itself. They also indicate that the median turn bay is quite important. Of course, at least in terms of eastbound traffic, the best option is to not have the driveway at all.

To carry this analysis of design features such as decel lane, accel lane, and median turn bay any further would require a sensitivity to detailed design features (e.g. effects of turning radii on vehicle speeds) which may not exist or would need to be calibrated into the particular tool being used, namely TRAF/NETSIM. Therefore, we will not overreach but will simply observe the importance of driveway design features as just summarized.

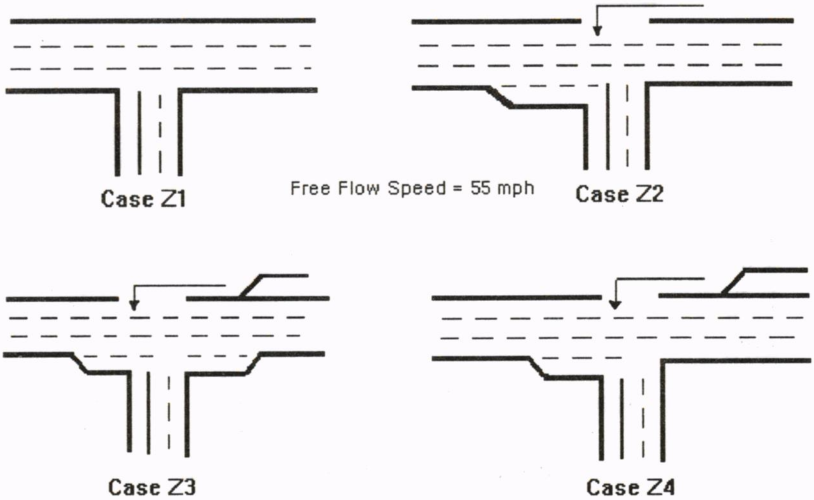
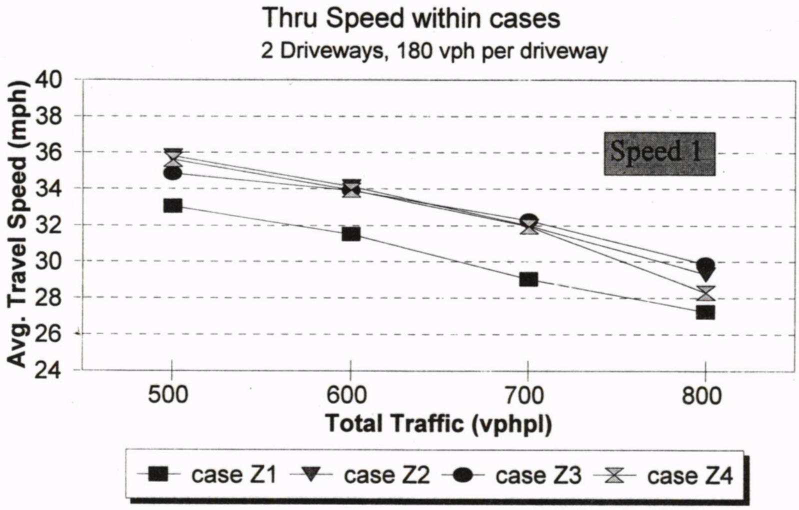
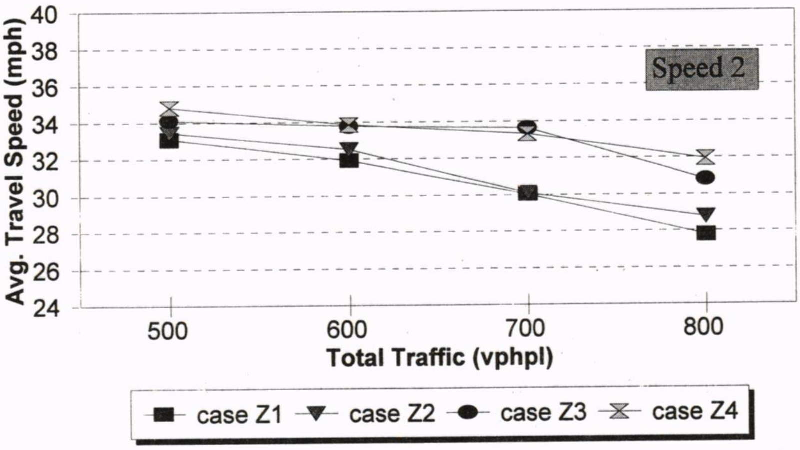


FIGURE 14: CONFIGURATIONS USED FOR MEDIAN TURN BAY



a) thru vehicle speed, eastbound



b) thru vehicle speed, westbound

FIGURE 15 : EFFECT OF MEDIAN TURN BAY

4. CONCLUSIONS

4.1 Analyses Insights

What are the characteristics of the "model arterial" in the present context, and how much do deviations from the ideal compromise its effectiveness?

First and foremost, the model arterial must have the signal spacing to deliver excellent progression to traffic in both directions. Driveways and other features cannot be located so that they represent the next generation's problem intersections or queueing areas.

This model arterial must also have the "side street" capacity to allow people to cross the arterial (or enter it) without needing unreasonable portions of the green time. When certain features --- driveways in particular --- are considered, they must be handled with great care. The access management literature advocates such basics as: no left turns across the centerline; fewer driveways; well-designed and smooth transitions from the arterial; driveways away from intersections. This study supports these positions, by demonstrating that it is all too easy to degrade the average travel speed of the thru vehicles by 5 mph, and that it is even possible to degrade the performance by up to 10 mph.

Lastly, it was made clear that decel lanes are important to the "near side" thru traffic when driveways are present, and median turn bays are important to the "far side" thru traffic.

This study has also provided a special focus on the performance of the true, defined arterial user, namely the thru vehicles. The average travel speed of these vehicles is often 4-5 mph higher than the overall averages, which has one set of implications. The thru vehicle average travel speed is also much more sensitive to degradation from adverse practices, which has another set of implications.

4.2 Issues Related to Access Management in Korea

Like most developing countries, most of developments in Korea are laid out along its roadways forming high-density stripe development. Some of the main reasons for that are poor land-use planning, improper provision of highways (roads hierarchy problem), its geographical characteristic that 70% of its total area is mountainous, and so forth. Thus in rural setting arterials with frontage roads are seldom found, and roadways forming urban network in major cities are mostly arterials with 6 lanes or more.

Furthermore, the auto-ownership has doubled in recent 5 years approaching 9.5 million automobiles in 1996. This naturally created skyrocketing demands for access to and from public roads, and many regional offices under the Ministry of Construction and Transport (MOCT) are at a loss about the situation since there is no firm guidelines and staffs are not well trained. Traffic accident rate is also high putting the nation on the highest 3rd in the world.

Problems like traffic congestion and accident are serious concerns to general public and commercial vehicle operators not only in urban area but also in most rural highways. In 1994, in order to maintain the integrity of road systems and lessen the problems such as traffic congestion and accidents, the MOCT initiated a research project titled 'Development of Access Management Code for Public Roads.' The research team had visited some of leading organizations like Colorado DOT, New Jersey DOT in the United States and decided to adopt basic frameworks from them. The team have retouched many of contents of American version considering Korea's legal, institutional, socio-economic and geographical setting that are different from the USA's.

Even though the Access Management Code was put out in no time, it is not being implemented mostly because well trained engineers are not available in the regional offices and the central government. The authors attribute the main reasons to the MOCT's internal administrative bottleneck, the lack of understandings toward traffic engineering and its typical mindset of *the status quo*.

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