ABSTRACT

BUGG, ZACHARY HOUSTON. Modeling Driver Lane Choice Behavior at Auxiliary Through Lanes (ATLs). (Under the direction of Nagui M. Rouphail, Ph.D.)

Auxiliary through lanes (ATLs) have typically been implemented as a cost-effective means of congestion relief at signalized intersections as an alternative to full roadway widening. However, the capacity of an ATL is generally less than that of a continuous through lane (CTL) because drivers tend to only use an ATL to avoid becoming stopped at the intersection at the end of the signal cycle. The research presented here describes the author's efforts to quantify the rationale behind driver lane choice at signalized intersections with an ATL. Specifically, this research contains two methods to quantify the flow in the ATL—using an aggregate and a disaggregate model. The aggregate model predicts the ATL flow as a function of macroscopic elements such as through-movement demand and signal timing. The disaggregate model describes individual driver lane choice as a function of instantaneous elements the driver experiences such as the queue in either lane. The results of the aggregate model development indicate that ATL flow tends to increase with through-movement demand and congestion, while right turns from a shared ATL tend to detract from ATL use.

Alternatively, the resulting disaggregate model indicates that the utility of the ATL increases as the CTL queue increases but that a driver's lane choice may also be dependent upon the displayed signal phase (effective red or effective green). After presenting the reasoning and methodology for the development of each type of model, the research shows a comparison of the two models and a summary of how each can be implemented within the context of current engineering process—both in the Highway Capacity Manual and using traffic simulation. The appropriate comparison between the models is achieved via Monte Carlo simulation to assume that the form of the input and output data for each model is identical. The results of the comparison indicate that the models yield statistically indistinguishable results, and these results are also statistically indistinguishable from the field data. The author then introduces a methodology to implement the aggregate model into the Highway Capacity Manual. Finally, the author recommends that the disaggregate models be implemented in microsimulation to either improve or replace the lane change algorithms currently used to control lane utilization in these systems.

Modeling Driver Lane Choice Behavior at Auxiliary Through Lanes (ATLs)

by
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To my mother, Barbara Youngblood Bugg

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LIST OF SELECTED ABBREVIATIONS / SYMBOLS

ATL	Auxiliary through lane
C	Cycle length, seconds
CTL	Continuous through lane
f_{LU}	Lane utilization factor
G^2	Likelihood ratio statistic
g	Effective green time, seconds
g/C	Effective green time to cycle length ratio
HCM	Highway Capacity Manual
LCD	Lane change distance, feet
MNL	Multinomial logit
MUTCD	Manual on Uniform Traffic Control Devices
pc/h	Passenger cars per hour
r^2	Coefficient of determination
s	Saturation flow rate, passenger cars per hour
spv	Seconds per vehicle
t	Student’s t test statistic
UDD	Upstream decision distance, feet
v/s	Volume-to-saturation flow rate ratio
vph	Vehicles per hour

X_R	Right turn demand-to-capacity ratio, equal to zero for an exclusive lane
X_T	Through movement demand-to-capacity ratio, assuming no ATL is present
χ^2	Pearson’s chi-squared statistic

1 INTRODUCTION

Auxiliary through lanes (ATLs) have typically been implemented as a cost-effective means to relieve congestion at signalized intersections and as an alternative to full roadway widening. While the term “auxiliary lane” may refer to many configurations in a traffic engineering context, for the purposes of this research the author defines an ATL as a through-movement lane that begins on the right-hand side, upstream of a signalized intersection and ends in a merge downstream of the intersection, as indicated in Figure 1-1. The original through lane(s) not discontinued downstream of the signal is labeled a continuous through lane (CTL). Figure 1-1A shows two *approaches* (one in each direction) with an ATL and one CTL. An ATL can be either a *shared* lane with right-turning movements (Figure 1-1A) or an *exclusive* lane, where right turns are made from an additional right-turn pocket (Figure 1-1B). Figures 1-1C and 1-1D also show shared and exclusive ATLs, respectively, for 2-CTL approaches. Figure 1-1A defines the ATL *upstream*, *downstream*, and *total length*. The following are several other assumptions regarding the scope of this research:

- All ATL approaches have one of the four basic configurations shown in Figure 1-1;
- All ATL approaches are equipped with an exclusive left turn lane (or, equivalently, there is no left turn demand on the approach); and
- The length of the ATL does not extend beyond a reasonable distance before or after the stop or beyond the nearest signalized intersection. The author assumes that drivers may regard an ATL with a very long upstream or downstream length as a continuous lane.

While this research concerns the basic configurations in Figure 1-1, the concept of an ATL and the implications of this research may be extended to other geometries, including the following configurations:

- A continuous lane that ends in a merge downstream of the intersection (this is equivalent to an ATL with a very long upstream length);
- An auxiliary lane that ends in a right-turn lane downstream of the intersection;
- Dual left-turn lanes onto a side-street or ramp where they merge into one lane downstream of the intersection; and

- An auxiliary lane on a roundabout approach.

While they contain a few similarities to the designs in Figure 1-1, these configurations are beyond the scope of this research.

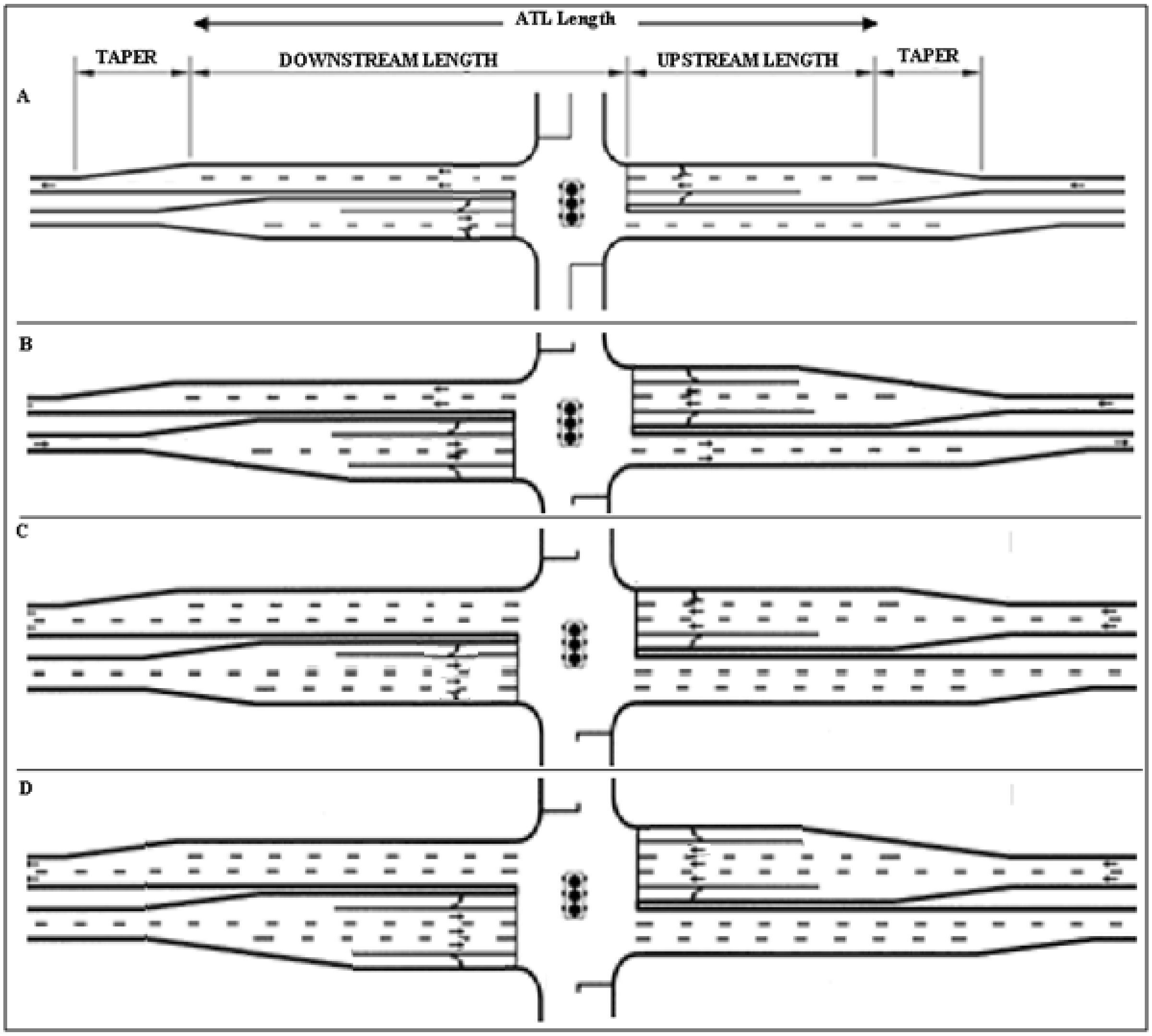


FIGURE 1-1. Auxiliary Through Lane Schematic
A. Shared 1-CTL B. Exclusive 1-CTL C. Shared 2-CTL D. Exclusive 2-CTL

1.1 Problem Statement

Since most congestion on access-managed arterials occurs at signalized intersections, in many situations ATLs are used as a relief measure when fiscal or land resources cannot be appropriated for widening across multiple intersections. They may also be installed as part of new development near an intersection. However, researchers and engineers have struggled to predict how many drivers will choose the ATL over the CTL(s) when they approach the intersection—this ultimately determines the benefit of using an ATL over a conventional intersection approach.

Although a national survey has found that ATLs are in place all across the United States, the Highway Capacity Manual (HCM) currently offers little guidance in the form of equations or a lane utilization factor to help determine the capacity and/or level of service of an ATL approach (*1, 2, 3*). Consequently, an engineer who considers building an ATL at a conventional intersection has no objective method to compare it to other alternatives. Likewise, there is no method provided to evaluate the level of service of an existing ATL approach. In the previously-mentioned survey, agencies from six states expressed a concern that local ATLs either experienced much less traffic than adjacent CTLs or were not designed to relieve congestion (i.e., the ATLs were constructed in conjunction with nearby land use development or widening of the other legs of the intersection). These responses, combined with the gap in the HCM regarding ATL capacity, lead to the primary question of the research regarding ATLs to date: what is the stimulus behind ATL use?

1.2 Research Objective and Contributions

The objective of this research is to identify those factors that influence ATL use in order to model driver behavior at ATLs. This research will ultimately provide practical models for ATL use and includes the following scientific contributions:

1. Development of a model to explain ATL use as a function of macroscopic factors that can be implemented in the Highway Capacity Manual to supplement the current guidance on lane utilization at signalized intersections. This type of model will be referred to in the remainder of this dissertation as an *aggregate* model;
2. Development of a behavioral model to explain driver lane choice at ATLs as a function of microscopic elements. This type of model will be referred to in the remainder of this dissertation as a *disaggregate* model;

3. Development of a method to compare the resulting aggregate and disaggregate models and determine whether the models yield statistically indistinguishable results; and
4. Development of methods to implement the aggregate models in the current HCM procedure as well as a discussion of the feasibility and high-level approach to use the disaggregate models as a means to improve the lane choice algorithms of microsimulation systems.

Although the scope of this study is primarily focused on the four ATL configurations identified in Figure 1-1, the contributions listed above will be developed so that they can be generalized and replicated for similar configurations (see the bulleted list before Figure 1-1).

1.3 Research Background

The most comprehensive investigation of ATL operations to date was conducted as part of *NCHRP Project 03-98: Guidelines for the Use of Auxiliary Through Lanes at Signalized Intersections* (*1*). In 2009 this project conducted a national survey that found that ATLs, though relatively uncommon when compared to conventional intersections, are nonetheless widely spread across the United States: the survey identified 63 potential study sites from 42 public agencies that responded. Approximately two-thirds of these sites each contained one CTL, while the remaining sites each contained two CTLs.

Table 1-1 lists 22 of the identified sites that were selected for this research—these sites were selected to represent a range of geographic location, congestion level, and ATL length, while being relatively free of obstructions (transit stops, railroad crossings, etc.) (*2*). The table lists the name and location of each approach, as well as the number of CTLs present and the type of ATL (shared or exclusive). The final column notes the average ATL utilization observed at these sites during the peak hour (expressed as a percentage of total through-movement flow); this is a relative indicator of how many vehicles use the ATL at these sites. The highlighting scheme reflects which ATL approaches are located at the same intersection. Much of the data extracted from these sites will be utilized in this dissertation.

TABLE 1-1. Summary of Identified ATL Approaches (*2*)

Approach Number	Intersection Number	Approach Name	Location	Number of CTLs	ATL Type	Average ATL Utilization (%)
1	1	EB Walker Rd at Murray Blvd	Beaverton, OR	1	Shared	28
2	1	WB Walker Rd at Murray Blvd	Beaverton, OR	1	Shared	29
3	2	EB NC-54 at Fayetteville Rd	Durham, NC	1	Exclusive	23
4	3	NB La Canada Dr at Magee Rd	Tucson, AZ	1	Shared	19
5	3	SB La Canada Dr at Magee Rd	Tucson, AZ	1	Shared	18
6	3	EB Magee Rd at La Canada Dr	Tucson, AZ	1	Shared	19
7	3	WB Magee Rd at La Canada Dr	Tucson, AZ	1	Shared	14
8	4	NB La Canada Dr at Orange Grove Rd	Tucson, AZ	1	Shared	19
9	4	SB La Canada Dr at Orange Grove Rd	Tucson, AZ	1	Shared	19
10	5	EB Walker Rd at 185th St	Beaverton, OR	1	Exclusive	40
11	5	WB Walker Rd at 185th St	Beaverton, OR	1	Shared	15
12	6	SB Sunset Lake Dr at Holly Springs Rd	Holly Springs, NC	1	Shared	9
13	7	NB Garrett Rd at Old Chapel Hill Rd	Durham, NC	1	Exclusive	19
14	7	SB Garrett Rd at Old Chapel Hill Rd	Durham, NC	1	Exclusive	23
15	8	NB MD-2 at Arnold Rd	Annapolis, MD	2	Exclusive	19
16	8	SB MD-2 at Arnold Rd	Annapolis, MD	2	Exclusive	20
17	9	EB MD-214 at Kettering Dr	Bowie, MD	2	Exclusive	5
18	10	NB IL-171 at IL-64	Melrose Park, IL	2	Shared	18
19	10	SB IL-171 at IL-64	Melrose Park, IL	2	Shared	18
20	11	NB-IL 171 at Roosevelt Dr	Melrose Park, IL	2	Shared	6
21	11	SB-IL 171 at Roosevelt Dr	Melrose Park, IL	2	Exclusive	26
22	12	SB US-1 at New Falls of Neuse Rd	Wake Forest, NC	2	Exclusive	13

Through video observation at the sites listed in Table 1-1, the author hypothesized several factors that could influence the level of ATL use at a particular site—these are listed in Table 1-2. These factors can be broken down into macroscopic factors, which may vary from site to site or from cycle to cycle, or microscopic factors, which vary based on each driver’s experience upon arrival at the intersection.

TABLE 1-2. Factors Hypothesized to Influence ATL Use

Macroscopic Factors		
Site Characteristics	Cycle-by-Cycle Factors	Microscopic Factors
• Location • ATL length (upstream, downstream, or total) • ATL type (shared or exclusive) • Signage of the ATL • Driveways along the ATL • Posted speed limit • Sight distance at the intersection	• Cycle length • g/C • Through-movement demand • Right turn demand • Arrivals during red	• Arrival phase • Queue length in each lane • Trucks in either lane • Right turns in a shared ATL • Green time remaining

The hypothesized macroscopic factors listed in Table 1-2 were identified based on the literature outlined in Section 2.1 as well as the author's observations and experience at ATLs. Driver behavior can vary from location to location, and areas where many ATLs are present may have drivers that are more familiar with ATLs and thus more comfortable using them. The ATL length (Figure 1-1), either expressed as the length upstream of the stop bar, the downstream length beyond the stop bar, or as the total length, was hypothesized to play a strong role in the operations of an ATL. Specifically, the upstream length must be adequately long to store the queue in each lane so that drivers can access the ATL, while the author hypothesized that the downstream length may provide a safety benefit as well as some level of comfort to the driver. Intuitively, exclusive ATLs and those without driveways along the upstream or downstream portions of the ATL would experience greater ATL use than shared ATLs or those with driveways because ATL users do not risk being delayed by right-turning vehicles. Drivers who make right turns from a shared ATL at the intersection or from an ATL into a driveway downstream of the intersection are referred to as "captive" users in this research. Additionally, the author hypothesized that sites with signage of the ATL as a through-movement lane would experience greater ATL use because drivers would be more encouraged to use the lane to move through the intersection. Sites with higher posted speed limits and design speeds were hypothesized to experience greater ATL use because of the potential for a greater speed differential between queued vehicles in the CTL(s) and arriving vehicles at the beginning of the green phase. Finally, the author hypothesized that sites with an adequate view of the entire ATL from the stop bar would experience greater ATL use because drivers would feel more comfortable using an ATL where they can see the entire merge area from the intersection.

Other factors were hypothesized to influence ATL use, although these factors varied from cycle to cycle. The principal factor here is congestion, with the idea that a more congested approach would experience a more equal split in driver use among the approach lanes. In terms of ATL use, congestion is made up of two primary elements: demand and signal timing. A greater amount of through-movement demand creates a heavier burden on the intersection, but a longer cycle length and smaller g/C create more queuing at the intersection. It is these long queues that the author hypothesized would lead to greater ATL use. Likewise, cycles with more arrivals during the red phase (i.e. poor signal progression) tend to have longer queues and possibly lead to greater ATL use.

The microscopic factors listed in Table 1-2 are based upon the author's experience observing patterns in driver behavior from an individual driver's standpoint:

- Queues in the CTL(s) and ATL, as well as the relationship between the two;
- Vehicle arrival times (after the beginning of either the red or green phase);
- Number of heavy vehicles (buses or trucks) in the CTL(s) or ATL; and
- Right turns, either from a shared ATL at the intersection or into driveways downstream of the intersection (the latter case would be an influencing factor to subsequent vehicles only if they were already within the intersection).

Although it was apparent that more drivers used the ATL as traffic increased on the approach, the author observed a pattern at a few of the sites: during each cycle the number of vehicles queued in the ATL would increase in proportion to the number of vehicles queued in the CTL. Figure 1-2 displays a sequence of video screenshots that shows this pattern. From top to bottom, in the first panel, the queue in the CTL is two vehicles, while the third vehicle used the ATL. The second panel indicates that after the CTL queue grew to four vehicles, the sixth overall vehicle that arrived at the intersection (the car in the foreground) chose the ATL. Finally, the third panel shows the extension of the pattern—the queue in the CTL is now six vehicles, with the ninth arriving vehicle (the white car) choosing the ATL. This pattern, which was observed at multiple ATL approaches, indicates that drivers have some perception of the trade-off between using the CTL and accruing more delay or using the ATL and having to merge past the intersection. Thus, the queue relationship (whether a difference or a ratio) between the CTL and the ATL likely has a strong influence on each driver's lane choice at the microscopic, disaggregate level. Similarly, at the aggregate level, this suggests that the CTL congestion level (a possible proxy for relative queue length) may be a strong indicator of ATL use.

FIGURE 1-2. Time-based Queuing Pattern during Red Phase

Intuitively, each driver chooses a particular lane in order to minimize his or her perceived travel time or delay over an arbitrary distance. From field observation it was hypothesized that the reasoning behind this varied with each vehicle's arrival time into the cycle. This logic can best be explained by assigning each vehicle to one of several categories based upon the time of arrival at a certain decision point (likely near the start of the ATL):

- Drivers who arrive during the red phase are generally content to stay in the CTL unless the queue length in the CTL(s) becomes too large. This leads to the previously-indicated queuing behavior where every third or fourth driver chooses the ATL. Drivers who choose to join the longer queue (in the CTL) presumably do so because they feel that they would be incurred the same amount of delay as if they had chosen the ATL and were forced to wait for a gap while merging back into the CTL downstream of the intersection.
- Drivers who arrive early in the green phase tend to follow the same logic—they perceive to some extent that if they join the CTL queue, then the green time would be long enough for them to clear the intersection. In terms of the perceived travel time in each lane, drivers' reasoning is likely similar to that in the previous scenario.
- Drivers who arrive later in the green phase generally only use the ATL to overtake vehicles in the CTL. They appear to perceive that the green phase would soon end and use the ATL to avoid the added delay of having to stop at the intersection, as displayed in Figure 1-3. The first panel in the figure indicates that a long queue has formed in the CTL by the time that the green phase begins (two vehicles are also queued in the ATL). The second panel displays that after the ATL queue has discharged and the CTL queue has begun to discharge, the approaching car chooses the ATL for fear of being stopped at the end of the green phase. To that effect, the third panel shows that after all ATL users have discharged, an approaching pickup truck in the CTL queue is forced to stop at the signal.

1. Signal Indication = Green
Long queue in CTL

2. Vehicle uses ATL to pass queue in CTL and avoid cycle failure

3. Signal Indication = Amber
Last vehicle in CTL queue not discharged

FIGURE 1-3. Example of Vehicle Using ATL during Green to Clear the Intersection

- Finally, drivers who initially choose to join the CTL queue sometimes switch to the ATL after the queue in the ATL has discharged in order to avoid being stopped at the signal at the end of the green phase.

Obviously, the above logic assumes that each driver has some ability to estimate the remaining green time at each intersection as well as the delay associated with the downstream ATL merge. Although pedestrian countdown timers were not present at all of the study sites, it can be assumed that some drivers may also have a sense of the green time remaining if they see the “flashing don’t walk” indication on the pedestrian crossing parallel to the through-movement. Alternatively, these drivers may simply travel these intersections regularly. Since nearly all of the data were recorded in urban or suburban areas during peak periods, it is a reasonable assumption that most drivers were commuters who were very familiar with the intersections. The queuing pattern in Figure 1-2 supports this hypothesis. Another assumption was that each driver always attempted to choose the lane to minimize his or her delay through the intersection. Although this may not always be the case—some drivers may avoid the ATL completely because of perceived risks in the downstream merge—it is assumed here that over months of commuting along the same route each weekday, drivers will become more comfortable with these risks.

Further review of the video data indicated that lane choice may be influenced by the types of vehicles in either lane. It can be assumed that most drivers are aware that trucks and buses cannot accelerate as quickly as passenger cars; consequently they may prefer the lane with the fewest heavy vehicles. For example, during one cycle in which a truck used the ATL, the queues in the CTLs grew extensively longer than the typical length at which a successive vehicle would use the ATL. Figure 1-4 illustrates this concept—note that the truck is the second vehicle in the ATL queue, but that the queue in the neighboring CTL is fourteen vehicles long.

FIGURE 1-4. Effect of Truck on ATL Use

The concept of lane choice can even be extended to these heavy vehicles—truck drivers may be courteous to other drivers by using the ATL to allow them to go around. On the contrary, some truck drivers may be less encouraged to use the ATL given the relatively long gap a truck requires to safely merge back into the CTL. Obviously, a bus may be forced to use the ATL if there is a bus stop near the intersection—this is similar to the concept of captive users who turn right at or downstream of the intersection into driveways.

1.4 Contribution to Practice

Each of the factors listed in Table 1-2 and discussed in this chapter can conceivably contribute to ATL use. The remainder of this dissertation concerns the development of a set of models that explain ATL use based upon the identified variables. There are several methods available to develop each model, and each of these will be described in the following sections. Ideally, such models will fit into the context of the HCM and other literature available to practitioners. Currently-used methods tend to over-predict ATL use and should be updated to reflect a more accurate model of ATL operations. As discussed later in Chapter 6 of this dissertation, the HCM also contains a few limitations regarding the treatment of ATLs with actuated signal control.

The models are also intended to be used to replace or improve the algorithms employed by microsimulation systems. These systems model the acceleration of individual vehicles using car-following algorithms, which are ultimately controlled by mandatory and voluntary lane changes (*4*). Although mandatory lane changes control necessary movements such as right turns or the downstream merge of an ATL, voluntary lane changes consist of movements that do not result in a different destination, a key example of which is the choice to move into the ATL. In areas where voluntary lane changes are permitted (e.g. upstream of a signalized intersection), the car-following algorithm takes effect. ATL use in microsimulation is primarily controlled by these car-following algorithms—particularly when vehicles move around long queues or slower-moving vehicles—but the simulated ATL use can be unrealistically high without specifically calibrating the lane change rules. A driver behavior model is necessary to improve these voluntary lane changes, particularly to specify the target lane of each vehicle, and Chapter 6 in this dissertation primarily concerns the development of such a model.

1.5 Dissertation Outline

The organization of this research can be outlined in eight chapters:

1. The first chapter in the dissertation gives an introduction to ATLs, defines the problem statement, and lays out the research objectives and contribution.
2. This chapter includes an introduction to the possible modeling techniques and a synthesis of the literature on ATL use and models.
3. The third chapter includes a published paper describing the approach, development, and implementation of the aggregate models to predict ATL use, including a summary of the data collected, the resulting models, and a discussion of the models. Several plots explaining the details of the data relationships and models not critical to the contributions are displayed in Appendix C;
4. The fourth chapter is similar to the third chapter, covering the disaggregate models and addressing the corresponding research contribution. Several plots explaining the details of the data relationships and models not critical to the contributions are displayed in Appendix D;
5. The next chapter is also a journal publication, which includes an evaluation and comparison of the models described in chapters three and four and the methodology used to compare the models. Several plots explaining the details of the data relationships and model comparison not critical to the contributions are displayed in Appendix E;
6. The sixth chapter contains a summary of how the research can be implemented into practice. Specifically, the chapter describes how the aggregate models can be incorporated into the HCM and how the disaggregate models can be implemented in microsimulation algorithms; and
7. The last chapter highlights the conclusions from the dissertation and provides recommendations for further research and implementation of the findings.

2 LITERATURE REVIEW

This chapter contains a synthesis of previous research concerning ATL operations, behavioral models, and microsimulation. Before describing previous modeling efforts it is imperative that the author reiterates the two classes of models with regards to ATL investigation: aggregate and disaggregate. *Aggregate* models consist of macroscopic parameters that are calculated over a time interval or fixed for a given site. Some examples of these parameters are flow rates, traffic demand, cycle length, green time, ATL length, driveway density along the ATL, and land use along the ATL. To date all modeling efforts specifically aimed at ATLs have only included these macroscopic variables. *Disaggregate* models concern individual drivers or vehicles (used interchangeably in this text) and are event-based (also referred to as microscopic). The explanatory variables in these types of models tend to vary with each vehicle (or each driver's perception) and may include instantaneous queue lengths, arrival times, and individual vehicle characteristics. The organization of this chapter is as follows: a summary of the literature relating to aggregate models for ATL use, a description of the data collection methods that the author considered for the research, a summary of modeling approaches that the author considered for the research, and an introduction to microsimulation lane choice algorithms.

2.1 Factors Associated with ATL Use

The following sections describe the previous research regarding the major operational and geometric elements that affect ATL use. When summarizing these previous efforts, it is important to define the term "ATL use," which can be quantified in one of at least three ways. The conventional method to express ATL use is through the utilization of the ATL as a percentage of total through-movement flow, as described in Equation 2-1:

$$ATL\ utilization = \frac{ATL\ through\ flow}{Total\ through\ flow} \times 100\% \tag{2-1}$$

This term is a useful way to express the tendency of traffic to use the ATL and to compare

ATL use across sites where prevailing traffic demand may vary. A similar term is the HCM lane utilization factor f_{LU}, expressed as follows (*3*):

$$f_{LU} = \frac{Average\ flow\ per\ lane}{Heaviest\ flow\ in\ any\ lane} \tag{2-2}$$

The HCM uses this factor to adjust the saturation flow rate of a particular lane group—otherwise, it would assume that all lanes are equally utilized. A third way to express ATL use is by simply calculating the through-movement flow in the ATL. Because it does not standardize the ATL flow by adjusting for the total through-movement flow on the approach, this method does not allow for a convenient comparison across sites. However, due to the explanatory variables involved in various modeling efforts, some analysts have chosen to use the third definition. In general, all of the previous ATL modeling efforts have used one of these three variables (ATL utilization, f_{LU}, or ATL flow) as the dependent variable.

Previous studies have included at least some of the following explanatory variables in their attempts to explain or predict ATL use:

- Total through-movement flow or demand, which may also be expressed as some form of the demand-to-capacity ratio to allow for changes in signal timing (*5*, *6*, *7*, *8*, *9*, *10)*;
- Travel time or delay, often used to compare the ATL to the CTL(s) (*9*);
- ATL upstream, downstream, or total length *(5*, *6*, *7*, *9*, *10*, *11*, *12*, *13*, *14*).
- Other elements, including ATL type (shared or exclusive), right turn flow from the ATL (if shared), land use adjacent to the ATL, and driveway density along the ATL (*5*, *6*, *8*, *11*).

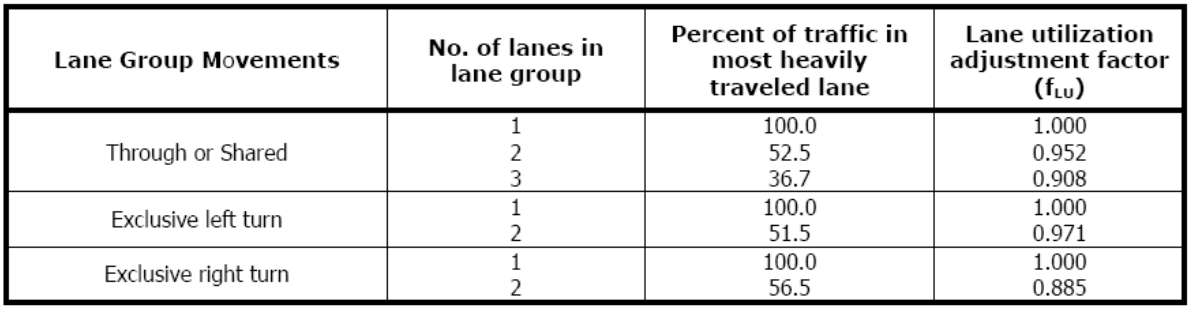
Instead of breaking down the literature study-by-study, the following subsections describe each of these explanatory variables and which studies support their influence on ATL use.

2.1.1 Through-Movement Flow or Congestion

Past research found that ATL use is primarily related to congestion in the through-movement lanes. In nearly all situations, unless drivers are prepositioning for a left or right turn downstream of a signalized intersection (captive drivers), they tend to fill the unused lanes. Thus, if one or more CTLs are heavily congested, drivers can be expected to switch from a CTL to the ATL. Lee et al. found that through-movement demand was a strong indicator of ATL utilization *(5)*. Furthermore, Hurley *(6)*, Tarawneh *(7)*, and Ring and Sadek (*8*) identified through-movement flow as a principle stimulus for ATL use. In an exploratory microsimulation study, ATL utilization was pre-specified to explore the relationship between ATL use and congestion level *(9)*. The authors found that the optimum ATL utilization (the utilization that minimizes the delay for ATL users only) increases with through-movement demand.

By default the HCM also assumes that ATL flow increases with total through-movement flow. The current lane utilization factor is applied to the capacity of each lane in a lane group to determine the level of service of an intersection approach (*3*). Thus, the saturation flow rate of the ATL is proportional to the saturation flow rate of the entire lane group, and vehicles are assigned according to an equal degree of saturation. The primary reasoning for much of the research described in this chapter is that, in general, the HCM default lane utilization factor is too high, as determined through field investigation in several studies (*5*, *6*, *7*, *10*). Table 2-1 displays the default lane utilization factor in the HCM 2010 (*3*).

TABLE 2-1. HCM 2010 Default Lane Utilization Factor (f_{LU}) (*3*)



Lane Group Movements	No. of lanes in lane group	Percent of traffic in most heavily traveled lane	Lane utilization adjustment factor (f_{LU})
Through or Shared	1	100.0	1.000
	2	52.5	0.952
	3	36.7	0.908
Exclusive left turn	1	100.0	1.000
	2	51.5	0.971
Exclusive right turn	1	100.0	1.000
	2	56.5	0.885

The table indicates an assumed ATL utilization of 47.5% for a 1-CTL approach and 26.6% for a 2-CTL approach, assuming an equal distribution between the two CTLs. These values are much greater than the average ATL utilization observed at the 1- and 2-CTL approaches listed in Table 1-1, which are 21 and 16 percent, respectively.

In the absence of a specific model predicting ATL use, traffic engineers typically default to the HCM and then use their own judgment to adjust for the presence of an ATL. Chapter 18 of the 2010 HCM uses a deterministic approach to compute the capacity of each lane group present at a signalized intersection. Lane groups are determined by movement, with all lanes making a particular turning movement (usually divided into left, through, and right) being grouped together. A shared lane is placed in a separate lane group. Figure 2-1 displays an example of the HCM lane group methodology for two different ATL configurations (*3*):

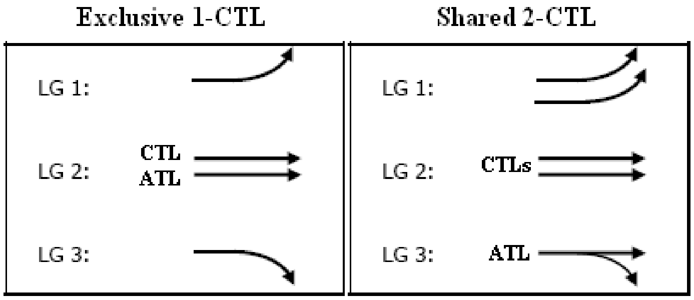


FIGURE 2-1. Lane Groups in the Highway Capacity Manual 2010 (*3*)

The figure indicates the difference in lane groupings as the number of CTLs and the type of ATL on the approach varies—thus, the corresponding shared 1-CTL and exclusive 2-CTL cases can also be incorporated into the lane grouping procedure. In the exclusive scenario, the HCM mandates that the CTL and ATL be included in the same lane group.

The next step in the procedure is to calculate the saturation flow rate using the lane utilization factor (f_{LU}) and so on, but as noted previously, this usually leads to an unrealistically-high ATL utilization (Table 2-1). In fact, the HCM warns that the lane utilization factors displayed in Table 2-1 do not apply to "short lane drops…that might cause drivers to intentionally choose their lane position based on an anticipated downstream maneuver" (*3*). Some methods are available for modifying this factor when an ATL is located in one of the lane groups (*8*). The chief disadvantage of this procedure with regard to lane utilization is the HCM treatment of shared lanes. If the ATL is shared, the HCM requires that it be treated as a separate lane group, which creates a confusing situation with regard to specifying the lane utilization factor. The question then becomes: which of the two factors will contribute more to the through movement flow in the ATL, the level of congestion, as implied by empirical data in much of the literature, or the impeding effect of right turns in the shared lane?

Additionally, the interaction between an ATL and actuated signal control is not considered in the HCM. Under actuated control, an increasing amount of volume will cause the green time to be extended during a particular cycle, thus allowing for more vehicles to clear the intersection. However, this effectively decreases the congestion for that approach, and under the author's hypothesis, this would likely lead to less ATL demand. In turn, fewer vehicles would cross the stop bar detectors, which would lessen the amount of time that the green phase is extended and therefore increase congestion. This process necessitates an iterative procedure and is discussed in Chapter 6 of this dissertation.

Although the HCM is regarded as a conventional approach to modeling traffic operations, it offers little insight on driver behavior. The HCM's ability to predict the saturation flow rate on an approach, which results from the use of the lane utilization factor, does not explain much about any one driver's behavior or stimulus to use a particular lane. Likewise, the interaction between ATL use and actuated signal control is not discussed in the HCM. Because of these issues, it is unlikely that the HCM alone can be used for an ATL use prediction model or a study of driver lane choice behavior.

2.1.2 Travel Time

A related stimulus for ATL use is the incentive for drivers to save travel time through an intersection, either by getting around slower-moving vehicles or, more importantly, to avoid being stopped at the signal at the end of the green phase. This effect was also shown in the microsimulation study by Alston, et al. by comparing two cases: in the first case, a specified number of vehicles were routed through the ATL, while in the second, all vehicles were routed through the CTL *(9).* The difference in travel time was then calculated by subtracting the average delay in the first case from the average delay in the second case. By considering the delay to ATL users, this method also considers right turns from a shared ATL that may detract from ATL use. The ultimate advantage of using delay savings or travel time difference as an explanatory variable is the ability to measure a threshold (e.g. five seconds of delay) below which drivers may not use the ATL because they do not expect to gain a significant benefit.

2.1.3 ATL Length

Another variable hypothesized to affect ATL use is the length of the ATL, quantified as either the downstream, upstream, or total length (Figure 1-1). Several studies have either made this same hypothesis or supported it with results *(5, 6, 7, 9, 10, 11, 12, 13).* Intuitively, drivers should feel more comfortable using an ATL with a higher downstream taper length because it allows them more space in which to merge. However, a study by Steyn and Vandehey refutes this hypothesis, indicating that lane utilization was nearly 50 percent even if one of the lanes ended shortly downstream of the intersection (*14*). Additionally, the Manual on Uniform Traffic Control Devices (MUTCD) advises against long downstream tapers because they may delay lane changing and cause sluggish driver behavior *(15).* The upstream length of the ATL, in contrast, is critical to its operation in that it should provide enough space for vehicles to readily access the ATL when the queue in the CTL(s) is long while simultaneously storing the queue from the ATL without it overflowing into the CTL (*13*). If the ATL upstream length is too short for either queue, *blockage* will occur.

2.1.4 Other Elements

The type of ATL and access management may also play a role in its utility. The presence of captive vehicles should intuitively discourage subsequent drivers from using the ATL and were also identified in Lee’s and Hurley’s studies *(5, 6)*. Conversely, McCoy and Tobin indicated that ATL use appeared to be unaffected by right turn volume as long as it was less than a quarter of the through-movement demand (*11*). Likewise, Ring’s study in Buffalo concluded that through-movement demand tended to diminish any negative effects caused by right turns from a shared ATL (*8*). One complicating factor is that these studies tended to investigate ATL use as a function of either right turn volume over a time interval (15 minutes to an hour) or driveway density. Neither of these methods reflects the effect of a captive vehicle on subsequent driver’s lane choice from an event-based perspective.

2.1.5 Factors Not Previously Studied

Although this chapter is focused on the hypotheses put forth by the literature, the author has also hypothesized several other factors that may influence ATL use, and it is important to highlight which of these may not be present in the literature but should still be considered in a study of ATLs. Intersection design elements that may be related to the ATL are the first type of factor not prevalent in the existing literature on ATL research. These factors are distinguished from the ATL length in that they are not directly related to the design of the ATL but may play a critical role in its operation. The author hypothesizes that drivers may feel more comfortable using an ATL that contains a merge area that is visible from the stop bar because this detracts from some of the risk associated with moving out of the ATL downstream of the intersection. Additionally, drivers may be more encouraged to use the ATL on a high-speed approach because the greater the posted speed limit, the more speed differential is created between vehicles queued in the CTL and arriving vehicles. These arriving vehicles may have more of an incentive to use the ATL to pass these queued vehicles just after the beginning of the green phase if they feel that they are traveling at a high enough speed to quickly overtake the queued vehicles and move back into the CTL just beyond the intersection. Furthermore, signage of the ATL may play a significant role in its operation. The author hypothesizes that if the ATL is signed as a through-movement lane, then this may positively influence a driver's decision to use the ATL. Alternatively, signage may have a negative effect on ATL use if there are too many signs present that indicate that the ATL ends beyond the intersection.

2.2 Data Collection Methods

The motivation behind this research was based on the author's observations of ATLs from video, but the author ultimately considered three techniques to collect data on driver behavior at ATLs. The following methods will be described in detail in the subsequent sections:

- Commuter Survey
- Driver Simulator
- Video from Field

2.2.1 Commuter Survey

The most basic method for collecting data for a study of driver behavior is to simply ask drivers why they choose a particular lane. Such *stated preference surveys* are typically conducted either in the field, mailed to drivers who commute through areas where driver behavior is studied, or conducted in an environment where drivers are shown video from a driver's perspective and then questioned about their behavior if placed in the hypothetical situation. These studies can yield direct answers to questions concerning driver behavior, and, if prepared correctly, can typically generate response rates of 20 to 40 percent (*16*). One of the most frequently used applications of a driver survey is to forecast travel patterns by collecting origin-destination data to produce trip tables. However, O-D surveys are often expensive to conduct and are gradually being replaced by U.S. Census travel-to-work data (*17*).

One such study surveyed driver perception of superstreet intersections by emailing surveys to commuters who potentially passed through the study intersections (*16*). The authors identified these commuters through the email database of a large local employer (the University of North Carolina at Chapel Hill). This email survey achieved a 20 percent response rate out of 2,520 recipients, and it was successful in identifying driver perception of the benefits and safety concerns of superstreets. A similar survey could be used to evaluate driver perception of ATLs and ultimately question their willingness to use the ATL given a range of events (e.g. queues, trucks, and arrival times). In any case, the disadvantage of such a study is the response bias, where respondents may be led to a particular answer simply because the presence of the ATL is acknowledged in the survey questions. Furthermore, the survey may be biased in that the subjects who actually respond to the survey may be more aggressive people who are more inclined to use the ATL.

2.2.2 Driver Simulator

Another method for investigating driver behavior is to observe drivers in a simulated environment where events and conditions such as queue lengths, ATL length, and signal timing can be varied and controlled. The advantage of this type of *revealed preference survey* is that it allows great control in experimental design and data collection, and this method is usually more cost-effective than field data collection over long periods and multiple sites. The downside of a driver simulator study is that it is time-intensive. Subjects must first be solicited and then trained to make the simulated environment realistic. The environment itself may also be difficult to create, especially signal head indications and non-linear behavior such as merging at ATLs.

One example of a driver simulator study was a 2011 study of driver yield rate at pedestrian crossings at roundabouts (*18*). The study included the design of a full factorial experiment complete with rotating treatments, including the offset of the crosswalk and the type of crosswalk control (beacon). The advantage of using the driver simulator in this study was the ability to vary conditions without putting real pedestrians in danger. Another study examined the effects of text messaging while driving (*19*). By using a driver simulator, the authors avoided placing subjects in a dangerous environment (i.e. texting behind the wheel). Advancements in eye tracking technology have also enabled researchers to gauge what subjects comprehend in the simulated environment—for example, the analyst could use an eye tracker to determine if drivers notice advance signage of the ATL as a through-movement lane (*20*). A comprehensive report by the USDOT identified several advantages and needs relating to current commercial vehicle driver training practices—many of these training programs use a simulated environment to prepare truck drivers for roadway incidents (e.g. tire blowout) (*21*). The study determined that the driver simulator was successful in reproducing the roadway environment, ultimately increasing drivers' safety and situational awareness.

2.2.3 Video from Field

Field observation is a popular method for collecting data in transportation studies (*22*). In this case the advantage is in the sheer number of data points available from the field, as traffic-based events are continuously occurring. The fact that the data are recorded onto DVDs allows the analyst to rewind and replay data as needed. The main concern of such a study is that the video must provide an accurate and consistent view of the events in question (for this study, the driver's lane choice). However, several of the study sites identified in this research were recorded with cameras placed upstream and downstream of the intersection, giving a full view of ATL operations, including driver lane choice and destination (i.e. whether or not an ATL user merged downstream of the intersection or instead turned into a driveway). Another disadvantage is that the analyst does not truly know what each driver is thinking as they approach the intersection, i.e. only the response is observed, and the factors influencing these drivers' lane choices must be inferred. This method is flexible in that it allows the analyst to collect more data at each site (in case the sample size limits the conclusiveness of the results) or at additional sites (for validation purposes) using the same methods of data collection. Because of the quantity and quality of ATL video data available, this was the author's preferred method for data collection.

2.3 Modeling Approaches

The author considered two model forms for investigating the stimuli for ATL use: aggregate and disaggregate. These methods have been investigated and used to model driver behavior in previous studies. Table 2-2 contains a summary and comparison of the characteristics of each type of model considered for this research.

TABLE 2-2. Model Characteristics

Model Type	Aggregate	Disaggregate
Form	Multilinear	Binary logit
Assumptions	Linear form, Independence of errors, Constant variance, No multicolinearity	Two possible outcomes, Independence of errors
Input	Through-movement demand, Right-turn demand, g/C, Saturation flow rate	Queues in either lane, Green time remaining, Time to clear intersection
Output	ATL through-movement flow	Probability of ATL use

This table is intended to give the reader a reference for the remainder of this dissertation, which refers back to these two model forms in numerous instances. The following section provides a description of each type of model, its assumptions, benefits, and drawbacks, and the previous use of the method within the context of transportation engineering.

2.3.1 Aggregate Models

Most of the studies described in Section 2.1 included the development of empirical models to predict ATL use as a function of macroscopic elements (e.g. flow, signal timing, ATL length, etc.). The primary method to develop these models is multilinear regression, which results in a general linear model in the form

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_k x_k + \varepsilon \tag{2-3}$$

where

y = dependent variable,

β_i = coefficients,

x_i = explanatory variables, and

ε = error (*23*).

Although the advantage of the multilinear model is its simplicity, the model contains two major assumptions:

- Foremost, the multilinear model assumes that the relationship between the dependent variable (expressed as ATL utilization, f_{LU}, or ATL flow) and each of the independent variables is linear. All exponential terms (e.g. ATL flow squared) must be treated as separate variables.
- The multilinear model also assumes that the error terms are independent and normally distributed with constant variance (*23*).

The assumption of independence may not hold over small time intervals. For example, if the multilinear form is used to model cycle-by-cycle ATL use and one or more vehicles are not discharged from the intersection by the end of the green phase, the increased queuing caused by lingering traffic at the intersection may lead to higher ATL use during the following cycle. This drawback can be mitigated by aggregating the data over multiple cycles (e.g. 15-minute data points), but higher levels of aggregation tend to muddle the range and effects of the independent variables.

The chief advantage of using these macroscopic methods to predict driver behavior (in the form of ATL flow rate) is that the models are easily applicable in the context of the HCM and current engineering practice (with a few notable exceptions—see Chapter 6 for a discussion of the HCM). Given the signal timing and turning movement counts, it is simple for a practitioner to use these models to predict the flow rate in a planned or existing ATL. In spite of the success of this modeling method, these models fail to explain the real stimulus behind each driver's lane choice and tend to smooth trends over long intervals (15 minutes to an hour). For example, refer back to the pattern displayed in Figure 1-2. From a macroscopic standpoint, it appears that one-third of the total through-movement traffic approaching the intersection used the ATL (half of the traffic in the CTL). In reality, ATL use at the intersection is based upon the queues—every third vehicle used the ATL during that particular cycle. Although this pattern could be implied by the ATL flow rate in either lane when measured at the macroscopic level, these aggregate models do not dictate the lane choice of individual vehicles based on instantaneous events—consequently, they likely cannot contribute much to microsimulation lane change algorithms.

2.3.2 Disaggregate Models

A discrete choice model is a common method for modeling driver behavior, particularly when the analyzed behavior involves a small number of discrete responses—lane choice is a primary example, but there are many others, including mode choice, route choice, and gap acceptance choice (*24*). In its most basic form, a model for unordered discrete outcomes can be expressed in a linear form:

$$T_{in} = \boldsymbol{\beta}_i \boldsymbol{X}_{in} + \varepsilon_{in} \tag{2-4}$$

where

T_{in} = a linear function that determines the discrete outcome i for the nth observation,

$\boldsymbol{\beta}_\mathbf{i}$ = a vector of estimable parameters for the ith discrete outcome (including an intercept term),

$\mathbf{X}_\mathbf{in}$ = a vector of the covariates that determine discrete outcomes for the nth observation, and

ε_{in} = disturbance term (error).

Assuming the form of the model is correct (i.e. all important data are available and the term $\boldsymbol{\beta}_i\mathbf{X}_{in}$ is linear), two types of discrete choice models are typically used: probit and logit. The difference between these is due to the assumed distribution of the error term ε_{in}. Probit models assume that the errors are normally distributed, while in logit models, the extreme value distribution (maximum, specifically) of the error terms is assumed to have the same form as the distribution of the error terms themselves, which is not the case for normally-distributed errors. While there are multiple distributions with this property, the most common form is the Gumbel distribution (*24*), in which the probability density function of the errors is

$$f(\varepsilon) = \frac{e^{-\varepsilon}}{(1+e^{-\varepsilon})^2} \tag{2-5}$$

with scale parameter. If there are *I* possible discrete choices (e.g. lanes to choose from), the probability of observing the i^{th} choice can be derived as

$$P_n(i) = \frac{e^{\beta_i X_{in}}}{e^{\sum_{j=1}^{I} \beta_j X_{jn}}} \tag{2-6}$$

which is known as the standard multinomial logit (MNL) model (*24*). Thus, the probability of observing each choice for the n^{th} driver can be estimated by computing the $\boldsymbol{\beta}_i\mathbf{X}_{in}$ term for the given choice and then dividing it by the sum of the $\boldsymbol{\beta}_j\mathbf{X}_{jn}$ terms for all *I* choices. The significance of each β term can be evaluated using the likelihood ratio test, the test statistic of which is given by the equation

$$\chi^2 = -2[\ell(\boldsymbol{\beta}_R) - \ell(\boldsymbol{\beta}_U)] \tag{2-7}$$

where

$\boldsymbol{\beta}_R$ and $\boldsymbol{\beta}_U$ represent the restricted and unrestricted parameter vectors, respectively;

represents the log-likelihood function; and

the test statistic has a chi-square distribution with degrees of freedom equal to the difference between the number of parameters in the restricted and unrestricted models (*24*). The overall fit of the model can be described by the McFadden ρ^2 statistic (similar to R^2 in regression analysis):

$$\rho^2 = 1 - \frac{\ell(\boldsymbol{\beta})}{\ell(\mathbf{0})} \tag{2-8}$$

Where the **0**-vector represents the model when all parameters are set to zero. This term is often penalized for the number of parameters *K* in the model by subtracting *K* from *l*(**β**) in the numerator.

In the case of modeling driver lane choice at ATL approaches, the complexity of the model depends on the number of CTLs present. For a 1-CTL approach, there are only two choices for each driver—the ATL or the CTL, but for a 2-CTL approach, there are three choices: the ATL or either of the CTLs. With three choices, the probit model becomes considerably more complex than the MNL model; the choice probabilities are not in closed form and require numerical methods to estimate (*24*). Although an ordered method would be preferred for the 2-CTL case, there does not appear to be any ordering with regards to each lane. Because of these issues and to be consistent with the 1-CTL case, the author will only consider logit models in this discussion.

Discrete choice models are not unfamiliar to engineers—in fact, they are used quite frequently by transportation researchers to model driver behavior. These models are often used in urban transportation planning where the utility of a certain transportation mode influences each individual traveler to choose that mode (*24*). For example, if two modes are being considered, then the utility of each mode for a certain traveler may be treated as

$$U_X = \sum_{i=1}^{n} a_i X_i \tag{2-9}$$

where

U_X = utility of mode *x*,

n = total number of attributes,

X_i = value of attribute representing time, cost, convenience, etc., and

a_i = coefficient value for attribute *i* (*24*).

Then the utility functions of two modes *A* and *B* can be compared using a logit model to determine the percent of travelers using each mode within a particular zone. For example, a transportation planner may develop a different utility function for each traffic analysis zone to account for varying demographics, mode choices, and other conditions. The probability of selecting mode A then becomes

$$P(Selecting\ mode\ A) = \frac{e^{U_A}}{e^{U_A}+e^{U_B}} \tag{2-10}$$

Similarly, the utility of an ATL may increase depending on specific traits of an approaching vehicle (e.g., if the vehicle is a captive or heavy vehicle) or operational conditions (e.g., if the green phase has begun but a queue still exists in the CTL) (*24*).

Perhaps the greatest use of discrete choice models in traffic operations has been in the field of gap acceptance modeling. Many of these efforts are aimed at estimating the critical gap, defined as the gap that a traveler is equally likely to accept or reject, for a driver or pedestrian. Since it reflects the willingness of drivers to accept a gap at an unsignalized intersection (including roundabouts) or merge point, the value of the critical gap has a large role in the capacity of such a design. Pollatschek used what he deemed a “decision model” to model driver behavior at unsignalized intersections based on the utility of time savings weighed against the risk of accepting a gap that is too small—this logic is similar to the tradeoff between ATL and CTL delay described in Section 2.1.2 (*25*). Troutbeck used the maximum likelihood method to calculate the probability of a critical gap to be between each driver’s smallest and largest acceptable gap (*26*). Since these smallest and largest acceptable gaps vary from driver to driver, the critical gap can be estimated for a group of drivers instead of for each individual. Schroeder and Rouphail also characterized the behavior of pedestrians at unsignalized crosswalks, specifically by modeling pedestrian gap acceptance trends (*27*). The researchers collected a large amount of data that included both discrete and continuous variables and used a logit approach. A number of studies have incorporated logit and discrete choice approaches to analyze driver yielding behavior at unsignalized pedestrian crossings. Sun validated such a model and drew conclusions about the relationship between driver age and gender, vehicle type, pedestrian platooning, and proximity to other yielding sites based on individual event-based observations (*28*). Schroeder and Rouphail conducted a similar study in North Carolina that used a logit model to predict driver yielding to pedestrians at midblock crosswalks (*29*).

There are also a few disadvantages to using the logit model to describe driver behavior. Other than the assumption that the model form is correct, the model also assumes that the error terms ε_{in} are independent (*24*). Although a driver's lane choice may obviously be affected by queue lengths, which are in turn a function of previous drivers' lane choices, this is not truly an issue of independence because it is assumed that each driver makes his or her own choice regardless of the previously-arriving driver's lane choice. It follows that the assumption of independence would only be violated if a driver was intentionally following a previous driver's decision, which is assumed to be a rare event. Furthermore, the model assumes that all possible choices are accounted for and that all significant explanatory variables are included in the model. Although the former is trivial, as there are only a fixed number of lane choices (two or three) for each approach, the analyst must strive to account for as many variables that may affect a driver's lane choice as possible in order to minimize error.

Another potential disadvantage of such a model is the necessity for a relatively large sample size to account for a range of events (i.e. queue lengths, captive vehicles, trucks in each lane, etc.). Although a few hours of video-recorded data may yield several thousand observations, it remains a possibility that not all realistic values and combinations of the independent variables may be accounted for. For example, it may be difficult to observe many cycles with more than one vehicle in the ATL queue at sites with low congestion levels (e.g. Site 12 in Table 1-1). Like most modeling efforts, the use of the discrete choice model typically requires validation with additional data to be widely applicable.

2.4 Driver Behavior Models and Microsimulation Lane Change Algorithms

When in need of data that cannot be easily obtained from the field (such as from unconventional designs like superstreets or multilane roundabouts), transportation researchers often look to microsimulation systems to collect data. Since input data (e.g. traffic flow, network design, signal timing) can be manipulated in microsimulation much more easily than in the field, traffic engineers often use this method when it is difficult to obtain a large and varied assortment of study sites. For these reasons, microsimulation is an acceptable method to consider when investigating driver behavior at ATLs, but such a model requires calibration with field data. Using a microsimulation system such as CORSIM or VISSIM to model traffic operations provides great flexibility in allowing the analyst to vary the input parameters and then determine the level of ATL use. These models also carry a few assumptions:

- Microsimulation primarily assumes that vehicles arrive randomly according to a Poisson distribution. Nonrandom arrivals often occur in the field (e.g. downstream of a signalized intersection), and they ultimately affect queuing behavior, and, consequently, ATL use (see the discussion of Figures 1-3 and 1-6). The analyst would have to take this into effect if the model were to be applicable to such a situation.
- Calibration is a meticulous exercise that also assumes that field conditions can actually be replicated in microsimulation. The strength of such a model, if developed, would be dependent on the range of ATL flow or utilization that could actually be predicted by the model.

Contrary to the queuing patterns and other observed driver behavior outlined in Chapter 1, simulated vehicles appear to lack the perception of the tradeoff between travel time savings and the risk of the downstream merge that real drivers likely consider when choosing a lane. The acceleration and lane changes of simulated vehicles are instead controlled by lane change algorithms, which are based upon vehicle destinations and speeds, as well as gap acceptance for the adjacent lanes (*4*). Thus, simulated vehicles do not truly behave like vehicles in the field when approaching an ATL, making microsimulation a poor candidate for development of a lane choice model as it is currently employed. However, if developed using another method, a behavioral model could improve the lane-changing algorithms of these systems so that simulated ATLs are more realistic. A discussion of this follows in Chapter 6.

One key contribution of this research is to test and, if necessary, update the lane assignment algorithms used in microscopic simulation packages such as VISSIM. Many of these microsimulation systems use a car-following model in which simulated vehicles adapt their speeds to the vehicles in close proximity to them (*4*). However, without calibration, these systems may assign more vehicles to an ATL than would otherwise be observed in the field. Consequently, simulated vehicles approaching an intersection will use an ATL only if they can move around slower (or queued) vehicles. In other words, these systems do not contain ATL-specific models, and ATL utilization must (but ultimately can) be user-defined and controlled, as Alston indicated (*9*). Although it is helpful to calibrate a simulated network to achieve the desired level of ATL use, it is more efficient to update the lane change algorithms of such systems so that they default to a more realistic (and accurate) level of ATL use without calibration. Other driver behavior studies have made similar contributions to VISSIM, including Schroeder's logit model of driver yield behavior at unsignalized pedestrian crossings (*29*).

A number of lane changing algorithms have been developed as part of the Next Generation Simulation (NGSIM) project. A 2004 study developed a lane choice model, dubbed a "Target Lane" model, for freeway lane selection based upon the utility of each lane (*4*):

$$U_{int}^{TL} = \boldsymbol{\beta}^{TL^{T}} \boldsymbol{X}_{int}^{TL} + \alpha_{i}^{TL} \nu_{n} + \varepsilon_{int}^{TL} \tag{2-11}$$

where

U_{int}^{TL} = utility of target lane i for driver n at time t,

$\boldsymbol{\beta}^{TL^{T}}$ = coefficient vector for X_{int}^{TL},

$\boldsymbol{X}_{int}^{TL}$ = dependent variable vector for the utility of lane i,

α_i^{TL} = coefficient for the random effect ν_n,

ν_n = error (distribution affects the model type), and

ε_{int}^{TL} = error associated with target lane utility.

Assuming that ν_n is Gumbel-distributed (see Section 2.3.2), the logit model is derived:

$$P\left(TL_{nt}^{i}\middle|\nu_n\right) = \frac{e^{(V_{int}^{TL}|\nu_n)}}{\sum_{j\epsilon TL} e^{(V_{jnt}^{TL}|\nu_n)}} \tag{2-12}$$

where $V_{int}^{TL}|\nu_n$ are the conditional utilities of each alternative target lane (*4*). Using a dataset of vehicle trajectories from freeways, the resulting model predicted the utility of each target lane as a function of vehicle speeds, acceleration, and spacing. Note that the target lane could be any freeway lane and not just the lane(s) adjacent to the vehicle in question. Although these explanatory variables are not expected to play a significant role in ATL lane choice, the method to develop this model provides a basis for the development of a lane choice model for arterials. With regards to arterial lane changing models, the study speculated that driver lane choice is chiefly influenced by safety, presence of heavy vehicles, and a potential speed gain.

To implement the target lane model in simulation, the authors of the NGSIM study used their own simulation package, MITSIM Lab (*4*). The algorithm includes a step called “TLProbabilityLookAhead” that computes the utility of each lane in the segment for each vehicle. The function in turn calculates the probability of changing lanes, and each vehicle makes the choice based on a random number draw. If a lane change is indeed warranted, the algorithm moves to the next step, "ExecuteLaneChange," which consists of a gap acceptance function that compares the vehicle's critical gap to the available gap. An available gap results in the vehicle physically moving to the new lane (*4*).

A related study developed a set of models for driver lane choice at signalized intersection approaches where the cross street was a congested arterial (*34*). The study used multinomial logit models to account for each driver's *target lane choice*, determined by each driver's planning capability and familiarity with the route. Each driver's *immediate lane choice* was also modeled—this choice was conditional upon the target lane choice and only specified an adjacent lane (i.e. there were only one or two possible values). Using the maximum likelihood method, the study estimated that the target lane choice was chiefly influenced by the expected maximum lane utility and the anticipated delay associated with each lane (as a function of queue length and queue discharge rate). The immediate lane choice was found to be influenced by the target lane itself and the distance of the lane away from the target lane (i.e. the driver is more likely to move in the direction of the target lane rather than away from it).

Like the freeway lane change model, the study recommended that the model results be implemented in MITSIM Lab in the form of a decision tree in conjunction with gap acceptance logic, as indicated by Figure 2-2.

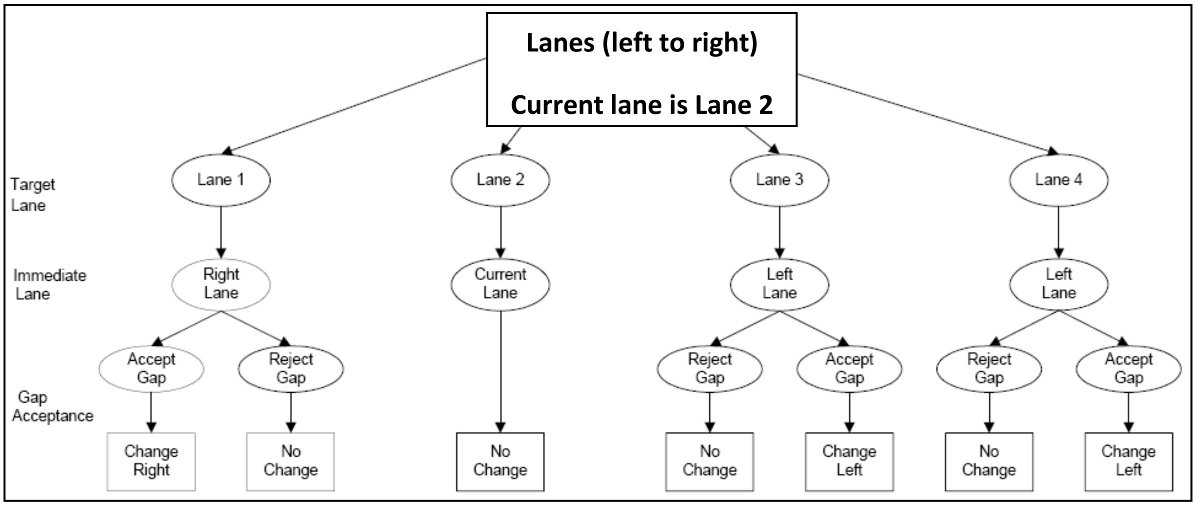


FIGURE 2-2. Arterial Lane Selection Model Decision Tree (*30*)

The figure indicates that the driver selects a target lane based upon turning movement and gap availability. After calibrating the model with field data collected using roadway sensors and origin-destination data, the study tested the validity of the model by measuring lane-specific flows and speeds, lane distribution, the number and location of lane changes for each vehicle, and the number of incomplete trips (*30*). Several measures of effectiveness were used to make the comparison, including root mean squared error, mean error, and the percent error versions of each (RMSPE and MPE). This validation exercise indicated that the new algorithms significantly improved the accuracy of MITSIM in simulating arterial lane choice. Although this study and others will likely continue to update microscopic lane change algorithms, to date no study has examined ATLs in this fashion.

2.5 Summary of Literature Review

From a review of the previous research pertaining to the stimulus for ATL use, it appears that a number of factors may be involved, including congestion, ATL length, arrival time, travel time / delay savings, queue lengths, and heavy and captive vehicles. The literature heavily supports the development of aggregate models, as many of the studies used macroscopic data to predict the ATL utilization or flow rate. However, these methods often smooth out underlying trends in the data and do not address the influence of causal variables on each driver's lane choice. Such models may be fairly accurate at predicting ATL use over a 15-minute or hourly interval, but these models are not helpful in terms of contributing to microscopic lane change algorithms. On the contrary, it appears that events in the field can be better modeled through an investigation of each driver's lane choice at a microscopic level by developing a behavioral model.

Microscopic methods are often used in transportation engineering to model driver behavior and may consist of microsimulation and discrete choice models. Microsimulation systems are easily manipulated and provide much more data compared to other microscopic methods, but they tend to over-predict ATL use and may not accurately account for factors which affect each driver's lane choice. It is for this reason that a disaggregate model is needed to improve the target lane algorithms of these microsimulation systems.

3 AGGREGATE MODEL DEVELOPMENT

This chapter describes the development of two aggregate models for ATL flow rate at signalized intersections. The bulk of this research was prepared as part of the author's contribution to *NCHRP 03-98: Guidelines for the Use of Auxiliary Through Lanes at Signalized Intersections* and a paper on the methods used to develop the models (*1*, *2*). The chapter contains a description of the methods used to develop the models, a presentation and investigation of the resulting models, and the author's recommendations on implementation. Chapter 6 of this dissertation contains two example exercises that demonstrate how the models can be used under actuated control within the context of the Highway Capacity Manual.

3.1 Introduction

Auxiliary Through Lanes (ATLs) are often implemented at congested signalized intersections where fiscal and right of way constraints do not allow for full roadway widening. Past research and experience suggest that the utilization of these ATLs is, in general, significantly less than the theoretical capacity of a continuous lane. However, there is currently little guidance concerning the operational and design factors that explain ATL use, and analysts often have no empirical basis for evaluating ATL operations in the context of the Highway Capacity Manual. This chapter presents detailed empirical observations from 22 ATL approaches from across the United States. These field observations are used to develop and validate statistical models to predict the through-movement flow in the ATL. The author also addresses the design elements of an ATL approach that may be related to ATL use.

3.1.1 Research Objective

The objective of this chapter is to understand which factors affect ATL use and what steps can be taken to increase the use of an ATL facility (if possible). This research was inspired by NCHRP 03-98, which led to the development of operational guidelines for an ATL that consider both operational and design parameters of the intersection (*1*). However, the methods presented in this chapter result in models that fit within the context of the Highway Capacity Manual, where they can ultimately be used to estimate the utilization of an ATL for an operational analysis of the intersection. The remainder of this chapter is organized as follows: definition of variables, methodology, resulting models, and conclusions.

3.1.2 Definition of Variables

The author considered several target and explanatory variables when developing the aggregate models, most of which were summarized in Chapter 2. Table 3-1 lists the primary target and explanatory variables considered for the model. The independent variables can be categorized into the following:

- Traffic Variables – those variables based on stream characteristics and turning demands,
- Geometric Variables – those variables describing the geometric elements of the intersection and ATL, and
- Signal Variables – those variables describing the signal timing (aggregated over multiple cycles in this chapter) and through saturation flow rate by lane.

TABLE 3-1. Definition of Dependent and Independent Variables

Variable Type		Name	Unit	Explanation
Dependent Variables		ATL flow	vph	15-minute flow rate, includes through traffic in the ATL only
		ATL utilization	%	ATL flow expressed as a percentage of total through-movement flow
Independent Variables	Traffic	Total through-movement flow	vph	15-minute flow rate
		Heavy vehicle flow	vph	15-minute flow rate
		X_T	None	$= \frac{ATL\ Flow + CTL\ Flow}{Capacity\ of\ CTL(s)}$
		X_R [1]	none	$= \frac{RT\ Flow\ (if\ shared)}{Capacity\ of\ Shared\ ATL}$
		Delay saving[2]	s	= Delay (assuming no ATL) – ATL Delay
		Saturation flow rate[3]	pcphpl	
	Geometric	Upstream ATL length	ft	See Figure 1-1
		Downstream ATL length	ft	See Figure 1-1
		Number of CTLs	binary	1 or 2
		ATL type	binary	= 0 if shared, = 1 if exclusive
		Posted speed limit	binary	= 1 if posted speed limit is greater than 45 mph, = 0 otherwise
		Presence of driveways	binary	= 0 if many driveways present along ATL, = 1 otherwise
		Sight distance	binary	= 1 if entire downstream ATL length visible from stop bar, = 0 otherwise
		Signage	binary	= 1 if overhead signage of the ATL as a through lane is present, = 0 otherwise
	Signal	Cycle length	s	
		Effective green time[4]	s	
		Signal progression	binary	= 0 if most vehicles arrive in green, = 1 otherwise

[1] X_R = 0 if right-turns are made from an exclusive lane

[2] Delay computed using 2010 HCM Chapter 18, $d_1 + d_2$ *(3)*.The initial delay (assuming no ATL) is CTL(s) delay assuming all through traffic uses CTL(s)

[3] Saturation flow rate calculated using the 2000 HCM field procedure *(3)*

[4] Effective green taken as the maximum effective green for actuated control signals

The dependent variable ATL through-movement flow rate was one of several candidate variables used to quantify ATL use. One option was to use the ATL utilization percentage directly; another was to simply determine the through-movement flow rate in the ATL. After examining several relationships between these two dependent variables and the values of X_T, delay savings, X_R, and through-movement flow rate, it was determined that ATL through-movement flow rate was a more appropriate dependent variable than ATL utilization. For example, compare the plots in Figures 3-1 and 3-2, which use ATL flow as the dependent variable, with the plots in Figures 3-3 and 3-4, which use ATL utilization as the dependent variable. Each marker represents a different ATL approach, and the type of ATL at each approach is indicated as shared (S) or exclusive (E). The number of CTLs (1 or 2) is also indicated. It is difficult to see a relationship between ATL utilization and either of the two independent variables shown, likely because ATL utilization inherently contains the total through-movement flow in the denominator.

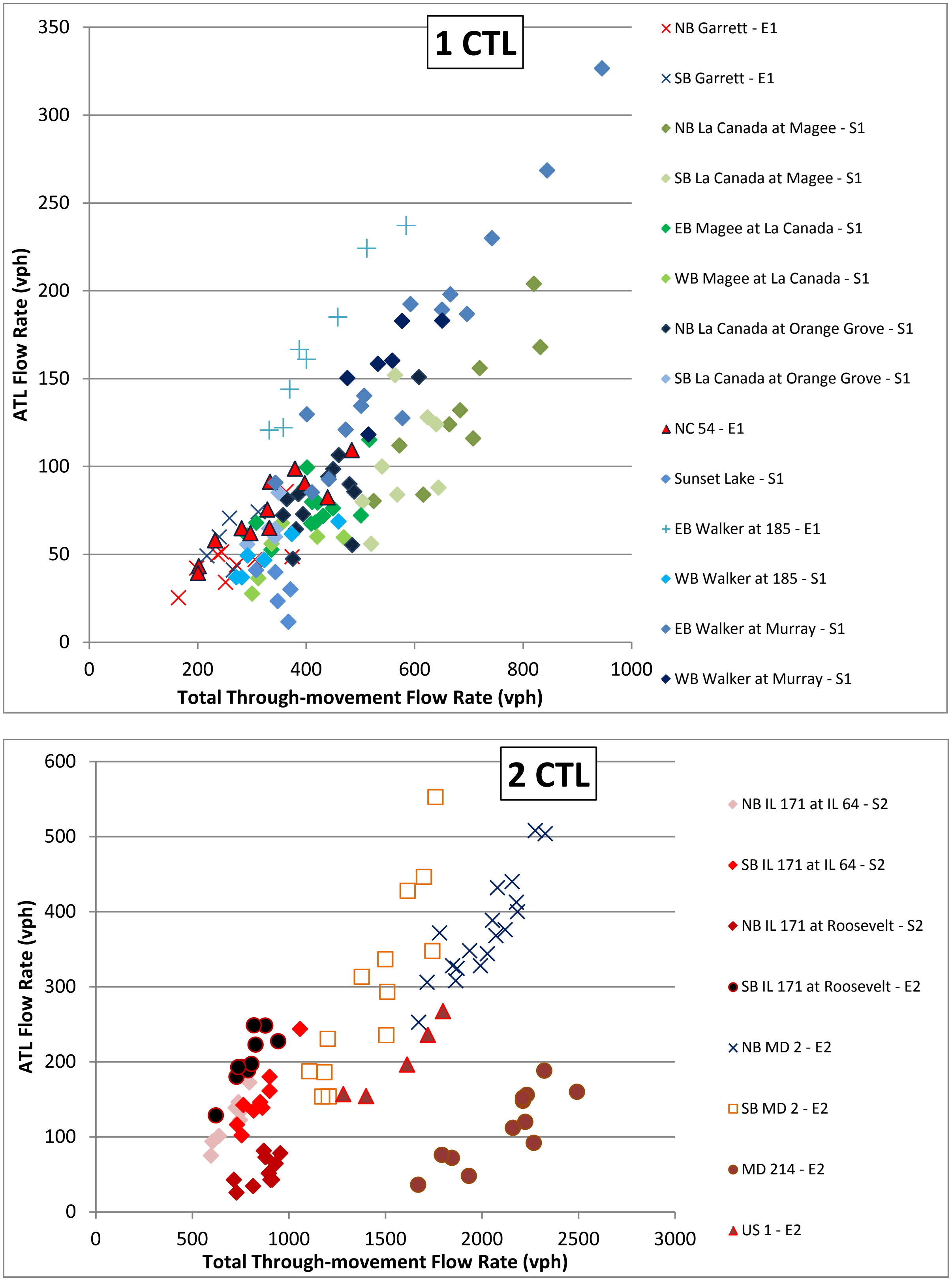
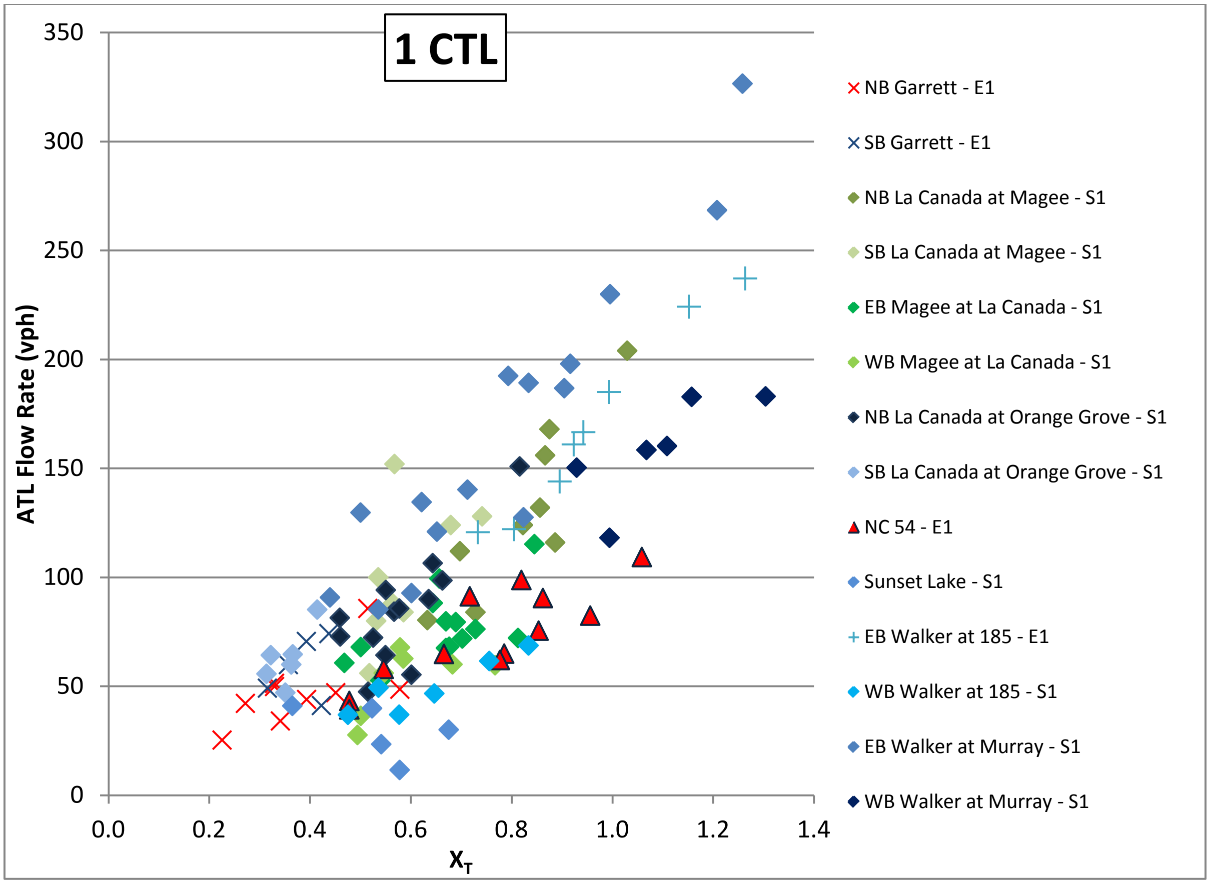


FIGURE 3-1. ATL Flow Rate versus Total Through-movement Flow



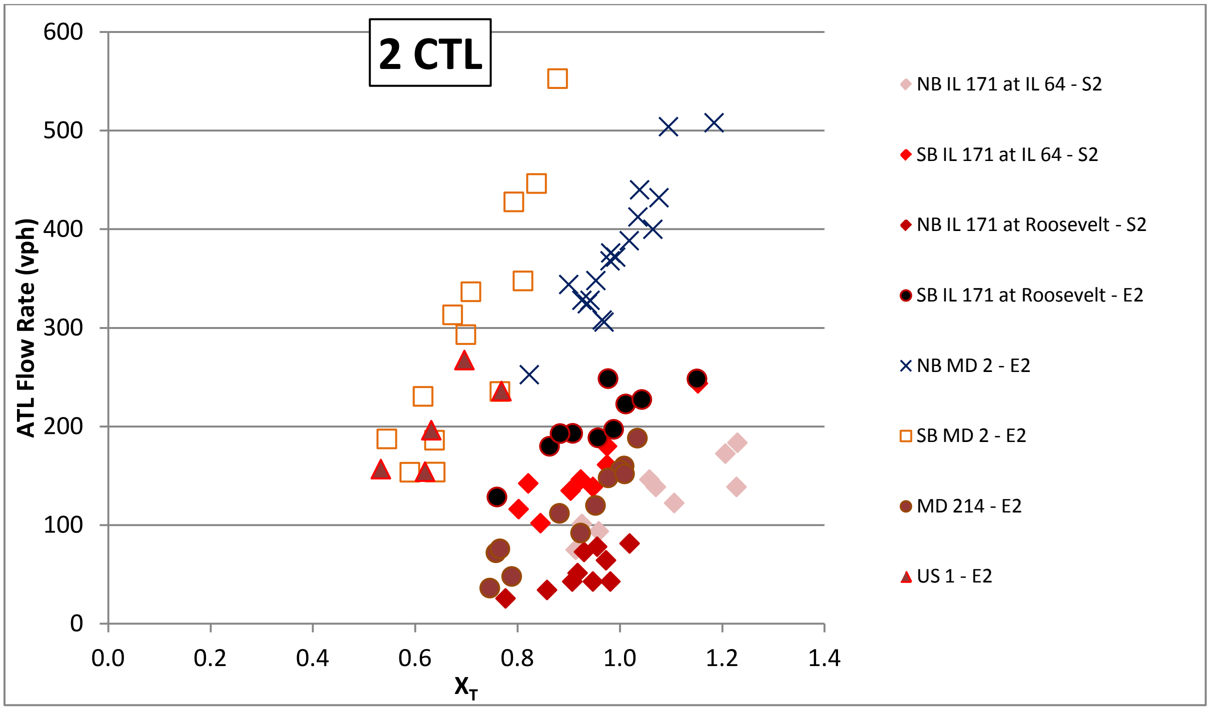


FIGURE 3-2. ATL Flow Rate versus X_T

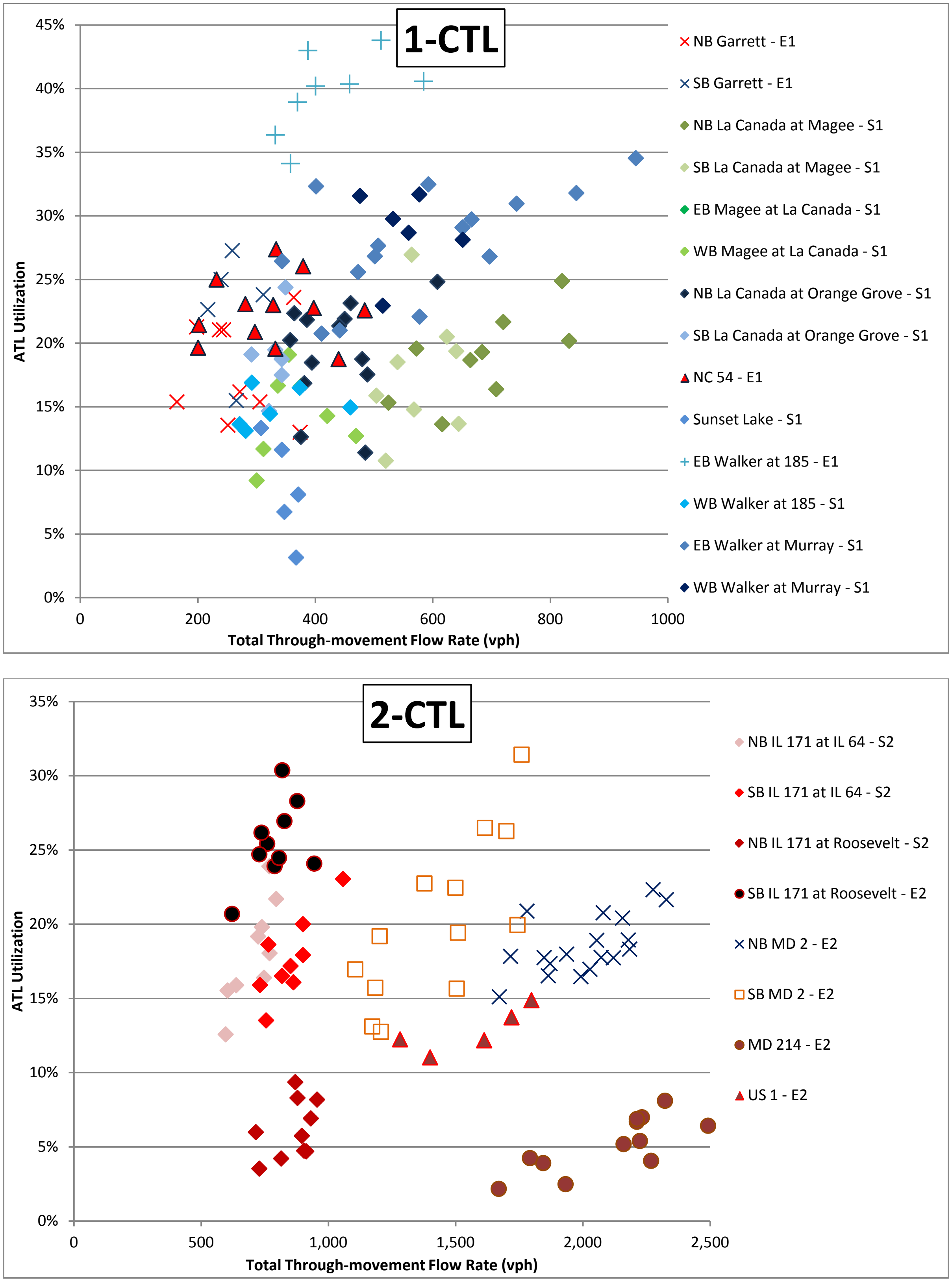
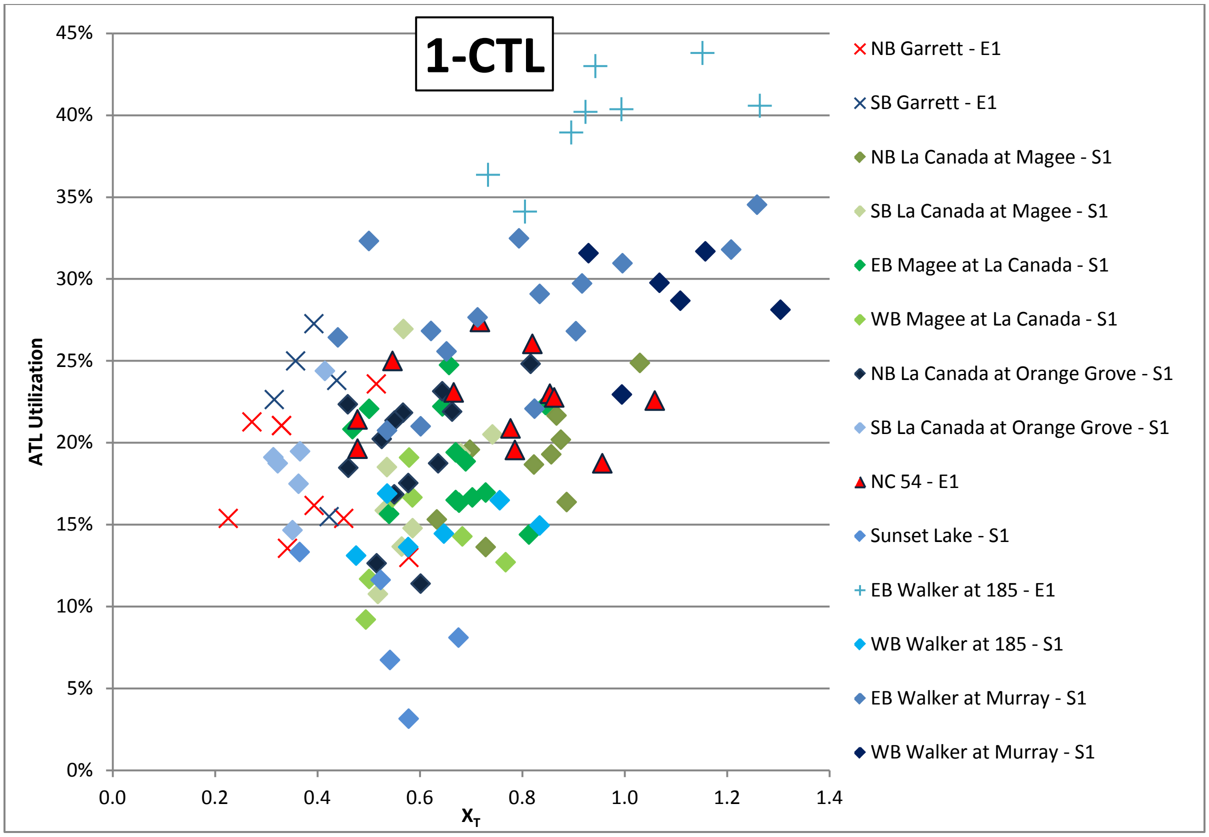


FIGURE 3-3. ATL Utilization versus Total Through-movement Flow



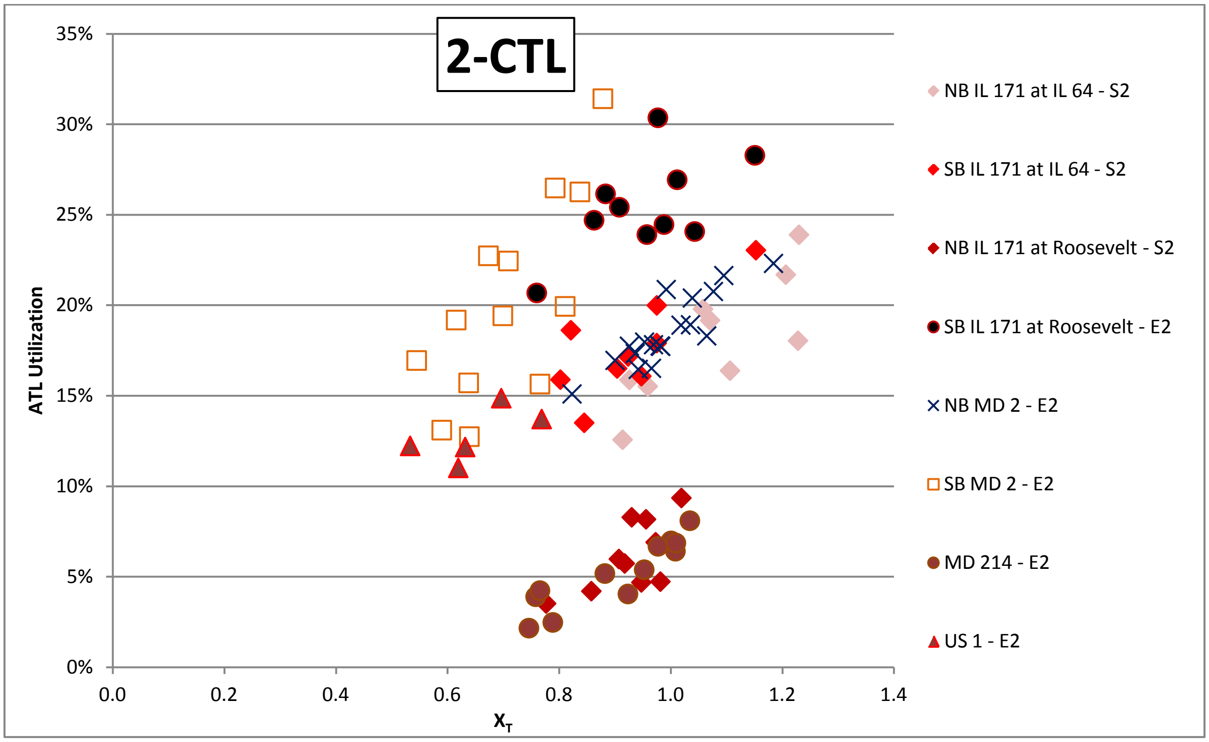


FIGURE 3-4. ATL Utilization versus X_T

Ideally, ATL utilization should be computed directly, but (with the exception of the 2-CTL plot in Figure 3-4) it does not appear to have any relationship with either total through-movement flow or X_T. The plots in Figures 3-1 and 3-2 indicate that ATL flow is strongly related to both through-movement flow and X_T. Although the data appear to be consistent between sites from visual inspection of the plots (especially for the 1-CTL sites), an ANCOVA analysis of this data (to test for site-to-site differences in slope) is contained in Appendix C. Note that the MD-214 site is an outlier (particularly in Figures 3-1 and 3-3). The author hypothesized that this site experienced relatively low ATL use in spite of high through-movement demand and X_T because of a high number of arrivals during the green phase. This was likely due to the platoon being progressed along the corridor from an upstream signal. Another interesting observation from the plots in Figures 3-1 and 3-2 is that the variance does not appear to increase as the values of through-movement flow and X_T increase, which is not consistent with count (typically Poisson-distributed) data (*24*). However, this trend is beneficial to the study in that it supports a multilinear modeling approach. Also note that in the 1-CTL data, the site-to-site variability does not appear to be much greater than the variability of the data within each site—this is further discussed in Appendix C.

The lack of a relationship between ATL use and ATL downstream length was quickly apparent to the author, as displayed in Figure 3-5, which plots the through-movement flow in the ATL against the downstream length for the 1- and 2-CTL sites separately (note that the scale varies). Note the lack of a positive relationship in the 1-CTL sites and a weakly-positive relationship for the 2-CTL sites. After investigating these relationships, the author concluded that while ATL upstream length may be critical to its operation (to allow for adequate storage of the ATL and CTLs), ATL use may not be related to the downstream length. Appendix C contains a further discussion of the ATL downstream length.

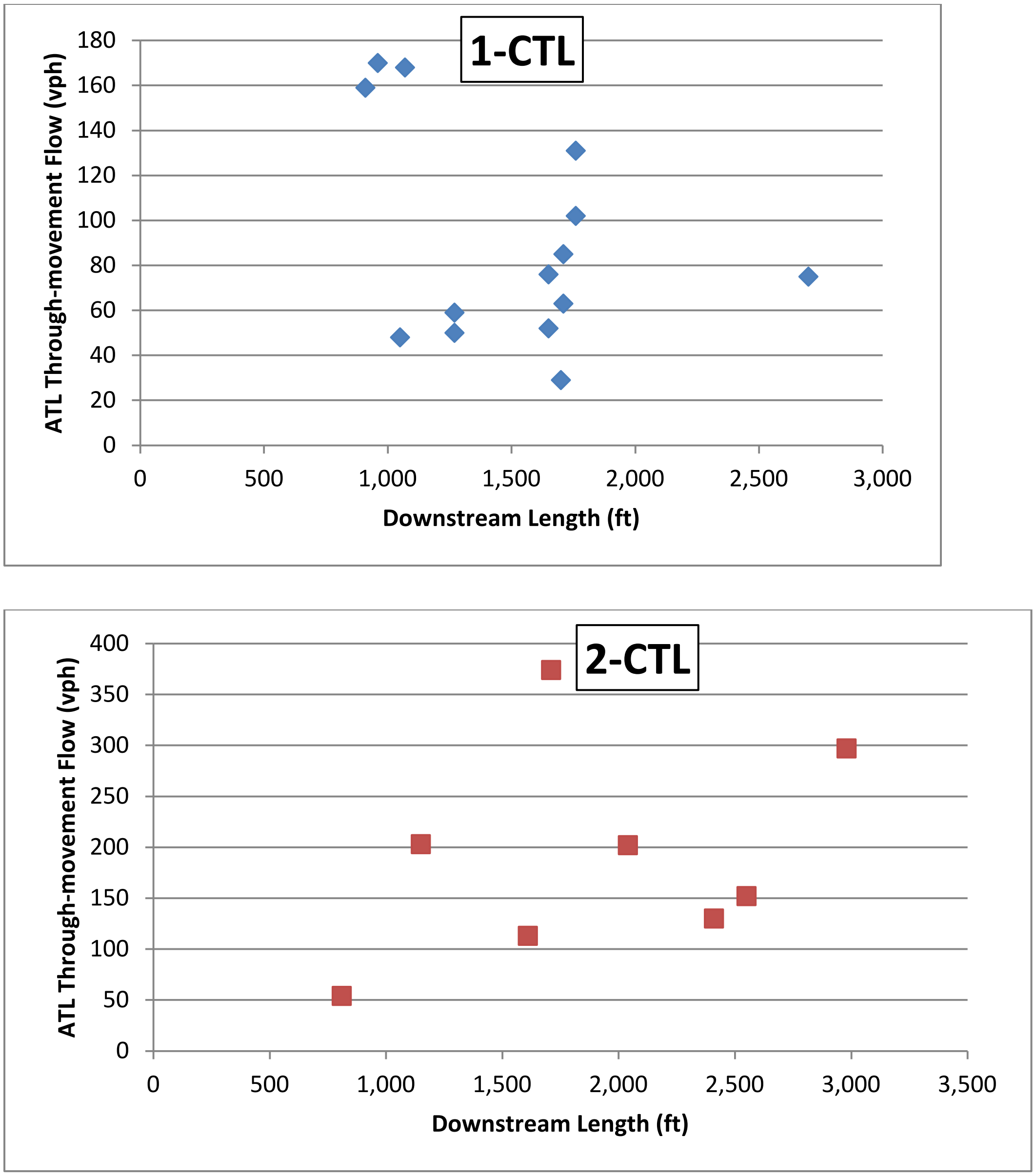


FIGURE 3-5 ATL Flow versus Downstream Length

3.2 Methodology

The following sections describe the methods used by the author to develop and validate the aggregate models. First the author describes how the data were collected from the field. Then the author explains the statistical procedure for developing the models.

3.2.1 Field Data Collection

The author collected a total of 52 hours of video data from the 22 ATL approaches listed in Table 1-1. Table 3-2 displays more details about each approach, including the number of 15-minute intervals collected, the total ATL length, and five binary variables that will be explained in Section 3.2.2.

TABLE 3-2. Summary of Aggregate Model Field Data

Approach #	Intersection #	Approach Name	Location	Upstream Length (ft)	Downstream Length (ft)	# of CTLs	Design Variables (Table 3-3)						*Average ATL Utilization %	# 15-min Field Data Points
							Speed	Shared	Driveways	Sight Distance	Signage	Design		
1	1	EB Walker Rd at Murray Blvd	Beaverton, OR	1,070	1,070	1	0	0	1	1	1	0.6	28	15
2	1	WB Walker Rd at Murray Blvd	Beaverton, OR	910	910	1	0	0	0	0	1	0.2	29	6
3	2	EB NC-54 at Fayetteville Rd	Durham, NC	2,700	2,700	1	0	1	0	0	0	0.2	23	12
4	3	NB La Canada Dr at Magee Rd	Tucson, AZ	1,760	1,760	1	0	0	1	1	0	0.4	19	9
5	3	SB La Canada Dr at Magee Rd	Tucson, AZ	1,760	1,760	1	0	0	1	1	0	0.4	18	8
6	3	EB Magee Rd at La Canada Dr	Tucson, AZ	1,650	1,650	1	0	0	1	1	0	0.4	19	13
7	3	WB Magee Rd at La Canada Dr	Tucson, AZ	1,650	1,650	1	0	0	1	1	0	0.4	14	7
8	4	NB La Canada Dr at Orange Grove Rd	Tucson, AZ	1,710	1,710	1	0	0	1	1	0	0.4	19	13
9	4	SB La Canada Dr at Orange Grove Rd	Tucson, AZ	1,710	1,710	1	0	0	1	1	0	0.4	19	6
1	5	EB Walker Rd at 185th St	Beaverton, OR	960	960	1	0	1	1	1	1	0.8	40	8
1	5	WB Walker Rd at 185th St	Beaverton, OR	1,270	1,270	1	0	0	0	0	1	0.2	15	6
1	6	SB Sunset Lake Dr at Holly Springs Rd	Holly Springs, NC	1,700	1,700	1	0	0	0	0	0	0.0	9	5
1	7	NB Garrett Rd at Old Chapel Hill Rd	Durham, NC	1,050	1,050	1	0	1	0	0	0	0.2	19	9
1	7	SB Garrett Rd at Old Chapel Hill Rd	Durham, NC	1,270	1,270	1	0	1	1	1	0	0.6	23	5
1	8	NB MD-2 at Arnold Rd	Annapolis, MD	1,710	1,710	2	1	1	0	1	0	0.6	19	18
1	8	SB MD-2 at Arnold Rd	Annapolis, MD	2,980	2,980	2	1	1	0	1	0	0.6	20	13
1	9	EB MD-214 at Kettering Dr	Bowie, MD	1,610	1,610	2	1	1	1	1	0	0.8	5	12
1	1	NB IL-171 at IL-64	Melrose Park, IL	2,410	2,410	2	0	0	1	1	0	0.4	18	9
1	1	SB IL-171 at IL-64	Melrose Park, IL	2,550	2,550	2	0	0	0	1	0	0.2	18	9
2	1	NB-IL 171 at Roosevelt Dr	Melrose Park, IL	810	810	2	0	0	0	1	0	0.2	6	10
2	1	SB-IL 171 at Roosevelt Dr	Melrose Park, IL	1,150	1,150	2	0	1	1	1	0	0.6	26	10
2	1	SB US-1 at New Falls of Neuse Rd	Wake Forest, NC	2,040	2,040	2	1	1	1	0	0	0.6	13	5

*Expressed as a percentage of total approach through-movement flow

For each approach, the effective green time *g*, cycle length *C*, and CTL, ATL, and shared right turn demand counts were extracted on a cycle-by-cycle basis. To mitigate the effect of random variation, the data were aggregated into 15-minute intervals (five to ten cycles depending on the cycle length) for model development. Due to high amounts of usable amber time observed from the field, the total lost time per each green phase was taken to be two seconds. To account for site-to-site changes in driver acceleration behavior, the author calculated the through saturation flow rate for each study approach in one of two ways:

1. If the approach contained one CTL, then the through saturation flow rate was estimated using the field procedure outlined in the HCM, averaged over 30 cycles *(3)*.
2. If the approach contained two CTLs, then the through saturation flow rate was estimated on a 15-minute basis using the HCM analytical computation and assuming a base saturation flow rate of 1900 passenger cars / hour / lane (pcphpl) *(3)*. This base flow was adjusted only for the number of heavy vehicles observed during the 15-minute period (other adjustment factors were assumed to be equal to one). The through saturation flow rate then reduced to

$$Through\ Saturation\ Flow\ (pcphpl) = 1900 \times \frac{1}{1+\%HV} \qquad (3\text{-}1)$$

   where %HV is the percentage of through-movement heavy vehicles, expressed as a decimal. This method was used only on the 2-CTL approaches because the saturation headway varied widely among cycles (1.5 to 2.5 pcphpl). The above equation resulted in a more reasonable (smaller) range of saturation headways.

These variables were used to calculate the operational parameters in Table 3-1 such as X_T and demand flow rates by lane. For a shared ATL, the ratio of the right-turn saturation flow rate to the through saturation flow rate was assumed to be 0.85, also consistent with the HCM *(3)*. Although the data were aggregated into 15-minute intervals, all demand counts were converted to hourly flows.

3.2.2 Model Development

Several models were developed using Statistical Analysis Software (SAS) *(31)*. A total of 122 1-CTL data points and 86 2-CTL data points were used in model development. Models were developed separately for the 1-CTL and 2-CTL data points because of hypothesized changes in driver motivation depending on the number of CTLs, as well as the tendency of the 2-CTL sites to have much higher demand (see discussion of Table 3-4). SAS stepwise regression was used to test for significance ($p < 0.05$) using the forward selection algorithm on the following independent variables (see Table 3-1 for explanation of units):

- X_T
- Through-movement flow rate (vph)
- Delay Saving (s)
- X_R
- Right-turn flow rate (vph)
- Heavy vehicle through-movement flow rate (vph)

These variables were identified from the earlier plots as those that were best-correlated with ATL flow rate. The square and square-root of each term were also included in the selection database to allow for non-linear behavior. After the most significant variables were identified by the stepwise regression algorithm, several combinations of these variables were evaluated using the GLM procedure for multilinear regression in SAS (*31*).

Using only the variables listed above, the models could explain nearly 80 percent of the variability in the 1-CTL data but only 35 percent of the variability in the 2-CTL data. The author then hypothesized that the data variability could be explained to site factors that influenced driver behavior at each ATL approach—this is particularly noticeable in the 2-CTL plots in Figures 3-1 and 3-2. An additional variable was then introduced to account for the signage and geometric design of each approach (Table 3-3). It was evident from the data that no single geometric feature was uniquely linked to increase ATL use, but higher

ATL use was observed for sites where multiple design elements favored or promoted ATL use. Since some combination of these variables was hypothesized to affect ATL use, they were grouped into a general binary variable, Design. This variable is determined by the equation

$$Design = \frac{Speed + Shared + Driveways + Sight\ Distance + Signage}{5} \tag{3-2}$$

After further examination of the data, the author elected to remove the MD-214 site because it was considered an outlier (noted above). Although all of the data collected should be considered when exploring the relationships between ATL use and operational and design elements of the intersection, the data trends for the MD-214 site were very different from those for all other sites, likely because of very low queuing (caused by good signal progression) at the MD-214 site. This site was not included in the model calibration dataset, and the author instead recommends that the models not be used to predict the ATL flow at sites where most vehicles are progressed in platoons through the green phase.

TABLE 3-3. Tested Design-Based Variables

Variable	= 0 (discourages ATL use) if	= 1 (encourages ATL use) if	Hypothesized Effect on ATL Use
Speed	Posted speed limit ≤ 45 mph	Posted speed limit > 45 mph	A high posted speed limit creates a speed differential that encourages drivers to use the ATL to pass queued vehicles in the CTL during the green phase
Shared	The ATL is shared with right-turns	The ATL is exclusive	Right-turns from a shared ATL discourage through-movement use of the ATL
Driveways	There are open commercial driveways or side streets in the downstream ATL	There are no open commercial driveways or side streets in the downstream ATL	Driveways/side streets create hazards in the downstream portion of the ATL
Sight Distance	There is an obstruction limiting the visibility of the downstream taper from the stop bar	The downstream ATL is clearly visible from the stop bar	Drivers are discouraged from using the ATL if they cannot see the downstream end
Signage	The ATL is not labeled as a through lane with overhead signs	The ATL is labeled as a through lane with overhead signs	Overhead signs encourage ATL use by indicating that is a through-movement lane

3.3 Aggregate Model Results

The following sections describe the field data used to develop the aggregate models, the statistical models themselves, and a discussion of the models.

3.3.1 Descriptive Statistics

Table 3-4 lists the minimum, maximum, mean, and standard deviation of several parameters extracted from field observations.

TABLE 3-4. Field Descriptive Statistics

Variable	Statistic	1-CTL	2-CTL	Combined
Sample Size		122	86	208
ATL Flow Rate (vph)	Min – Max	12 – 327	26 - 553	12 - 553
	Mean	96	210	143
	Standard Deviation	56	127	108
X_T	Min – Max	0.23 - 1.30	0.53 - 1.23	0.23 - 1.30
	Mean	0.67	0.91	0.77
	Standard Deviation	0.23	0.16	0.24
X_R	Min – Max	0 - 0.53	0 - 1.01	0 - 1.01
	Mean	0.14	0.20	0.17
	Standard Deviation	0.23	0.31	0.22
Delay Saving (s)*	Min – Max	3 – 139	7 - 150	3 - 150
	Mean	19	44	30
	Standard Deviation	25	27	29
Through Flow Rate (vph)	Min – Max	165 - 946	596 - 2492	165 - 2492
	Mean	435	1377	825
	Standard Deviation	152	583	608
Right Turn Flow Rate (Shared Lane Only) (vph)	Min – Max	16 – 241	94 -384	16 - 384
	Mean	118	227	144
	Standard Deviation	56	78	77
*Using HCM Delay Models *(3)*				

It is evident from Table 3-4 that the 2-CTL sites exhibit the upper extreme of most of the variables, which justifies the development of separate models for 1-CTL and 2-CTL sites. Of these variables, through-movement flow rate and X_T appear to be the principle factors that influence ATL flow rate, as shown in Figures 3-1 and 3-2.

3.3.2 Calibrated Aggregate Models

Tables 3-5 and 3-6 lists the primary models developed from the 1- and 2-CTL calibration dataset, respectively. The highlighted rows indicate models that have one or more terms that are not significant ($p > 0.05$), but these are included in the tables for purposes of completeness. The table also displays the model mean squared error (MSE) and error degrees of freedom (df).

The models in Table 3-5 indicate that ATL flow is related to X_T and the total through-movement flow (the latter term was divided by 100 to more appropriately scale the coefficient), which is consistent with the hypotheses that ATL flow rate increases with increasing through-movement flow rate and congestion level as indicated by X_T. The intercept term of several of the models indicates that there is some base disutility to using the ATL, as indicated by the negative sign, while the intercept is positive in other cases. The squares of the terms X_T and through-movement flow were also included in several of the models, although this tends to produce a positive intercept term. ATL flow tended to be negatively influenced by X_R but positively influenced by the design variable, which was also consistent with the author's hypotheses. Furthermore, each model explained 60 to 80 percent of the variation in the data. Although the total through-movement flow and X_T are obviously correlated, as they both consider the through-movement demand and in fact have a correlation coefficient of 0.5, the author felt justified in using both terms to explain ATL use, as the models which contained both terms explained much more of the data variability (R^2 = 70 to 75 percent versus R^2 = 60 to 65 percent) than the models that simply contained one term or the other. Several of the models in Table 3-5 explain much of the variability in the data while using only one or two explanatory variables, but model 108 achieved the highest R^2 (78 percent).

TABLE 3-5. Summary of Tested 1-CTL Models

Model	Intercept		Through Flow/100		Through Flow^2/10,000		X_T		X_T^2		X_R		Design		MSE	Error df	R^2
	Value	Std Error	Value	Std Error	Value	Std Error	Value	Std Error	Value	Std Error	Value	Std Error	Value	Std Error			
101	-30.7	9.46	29.1	2.10											1,172	120	0.626
102	35.0	5.21			2.88	0.20									1,142	120	0.636
103	-31.0	9.48					190	13.4							1,172	120	0.626
104	30.7	5.15							131	8.47					1,052	120	0.665
105	-52.6	8.62	17.0	2.50			111	16.1							843	119	0.734
106	-15.8	7.95			1.75	0.22	112	14.7							776	119	0.755
107	-15.7	7.69	16.2	2.20					82.6	9.68					734	119	0.768
108	20.2	4.40			1.65	0.21			81.8	9.27					696	119	0.780
109	-28.2	9.25	30.7	2.10							-67.0	24.3			1,111	119	0.649
110	40.7	5.60			3.01	0.20					-59.3	24.0			1,096	119	0.654
111	-30.4	9.81					191	13.6			-6.48	24.2			1,181	119	0.627
112	30.5	5.92							131	8.55	1.76	22.9			1,060	119	0.665
113	-30.8	9.60	29.0	2.20									0.728	7.24	1,182	119	0.626
114	32.7	6.20			2.83	0.21							4.86	7.02	1,147	119	0.637
115	-56.8	9.19					191	11.6					36.8	5.81	884	119	0.721
116	1.97	5.63							133	6.95			40.2	5.20	707	119	0.777

TABLE 3-6. Summary of Tested 2-CTL Models

Model	Intercept		Through Flow/100		Through Flow^2/10,000		X_T		X_T^2		X_R		Design		MSE	Error df	R^2
	Value	Std Error	Value	Std Error	Value	Std Error	Value	Std Error	Value	Std Error	Value	Std Error	Value	Std Error			
201	-35.1	19.9	20.7	1.50											4,417	72	0.737
202	88.2	12.3			0.740	0.0517									4,363	72	0.740
203	126	85.5					110	92.8							16,465	72	0.019
204	172	46.9							63.1	52.4					16,452	72	0.020
205	-141	46.4	20.8	1.41			116	46.4							4,116	71	0.758
206	32.3	44.3			0.735	0.0515	62.5	47.6							4,319	71	0.194
207	-92.0	29.5	20.8	1.41					66.5	26.2					4,105	71	0.759
208	57.4	25.3			0.735	0.0515			37.3	26.9					4,307	71	0.747
209	29.2	28.1	17.3	1.77							-90.3	29.3			3,951	71	0.768
210	136	17.4			0.611	0.0594					-101	27.6			3,726	71	0.781
211	63.8	58.5					257	65.0			-302	32.7			7,604	71	0.553
212	178	32.1							140	36.8	-298	32.8			7,711	71	0.547
213	-122	28.3	16.8	1.66									244	61.0	3,653	71	0.785
214	-29.8	28.8			0.595	0.0564							258	58.3	3,465	71	0.796
215	-371	77.8					242	63.7					673	71.2	7,395	71	0.566
216	-255	56.0							128	36.2			663	71.6	7,555	71	0.556

ATL use at the 2-CTL sites tended to be influenced more by the pure through-movement flow than by X_T, although the latter term was still significant to some of the models. The term X_R still tended to detract from ATL flow, but the design variable tended to have a heavier effect on ATL use for the 2-CTL sites than for the 1-CTL sites, likely because there was more variation among the 2-CTL sites. Again, several models explained much of the data variability with only one or two explanatory variables, but model 209 achieved the highest R^2 (76.8 percent) of the models with statistically significant terms. For both the 1-CTL and 2-CTL data, the author could not find any significant relationships between ATL flow and either ATL downstream length or heavy vehicle flow. Data plots showing the lack of a relationship in these cases are contained in Appendix C.

3.4. Summary of Aggregate Models

The research described in this chapter indicates that when ATL flow is modeled as a function of data aggregated from multiple signal cycles into 15-minute intervals, the following operational and design elements may be related to the flow in the ATL:

- Total through-movement demand,
- Right turn demand from a shared ATL,
- Number of CTLs present,
- Saturation flow rate
- g/C
- Posted speed limit
- Presence of driveways along the ATL,
- Presence of an exclusive right turn lane,
- Sight distance of the ATL merge area from the stop bar,
- Arrival type (random or mostly in green), and
- Signage of the ATL as a through-movement lane.

Most of these elements were hypothesized by the author and the literature to affect ATL use.

However, perhaps the most interesting conclusion from the research in this chapter is that the length of the ATL did not play a role in the models. In particular, the author observed that some of the sites with the shortest ATL lengths had the highest level of ATL use (sites 1, 2, and 10 in Table 3-2). Obviously, the upstream length of the ATL must be adequately long to store the queues in the ATL and CTL(s), but apart from this it appeared that additional ATL length had no operational benefit.

Regarding future research, the author suggests that the methods described here be expanded to similar ATL facilities (Chapter 1) that involve lane drops downstream of an intersection. Data from additional sites could also be collected to improve the models here and to validate the results. Since an underutilized ATL offers little benefit to the capacity of an intersection, more research could be performed on how to improve the use of an existing ATL, whether by driveway removal, the addition of signage, or the conversion of a shared ATL to an exclusive ATL. This and other studies have attempted to model delay savings for an aggregated number of vehicles using the control delay equations in Chapter 18 of the 2010 HCM (*2*, *3*). However, the results of these studies indicated that it was difficult to find a relationship between ATL flow, a macroscopic variable that varied from cycle to cycle (or even hour to hour), and delay, a microscopic variable that varied from vehicle to vehicle. Furthermore, examining the relationship in this fashion is flawed because as ATL use increases, the total delay for all vehicles will tend to decrease, but the average delay for vehicles using the ATL will tend to increase.

The relationship between ATL use and delay may become more apparent if the delay savings is computed for each vehicle using the equation

$$\text{Delay saving} = \text{Travel time (if not using the ATL)} - \text{Travel time (if using the ATL)} \qquad (3\text{-}3)$$

Note that the delay accrued by ATL users in the merge downstream of the intersection is almost always insignificant when compared to the control delay at the intersection (*2, 9*). Although each vehicle can only choose one lane at a time, the delay for the alternative case can be computed using either the HCM equations or estimated by taking the difference in travel time for a vehicle that chooses the ATL and a successive vehicle that did not, given that the difference between their arrival times is small. This microscopic approach, which takes each vehicle’s perceived delay savings into account, may be more successful than calculating the delay for a group of vehicles over a time interval—this type of approach is considered in the develop of a disaggregate model in Chapter 4, and the resulting models of such research may be useful in microsimulation systems—this is discussed in Chapter 6.

4 DISAGGREGATE MODEL DEVELOPMENT

This chapter describes the development of a disaggregate model for ATL lane use. Previously-developed models have predicted the flow in the ATL as a function of macroscopic elements, such as through-movement demand and signal timing. However, these models do not explain each driver's behavior or motivation to use the ATL, nor can they be used in the field of microscopic simulation models. This chapter presents an empirically-developed model for driver lane choice at signalized intersection approaches with one ATL and one continuous through lane (CTL). The models are also compared to a validation site from outside the dataset. Much of the research presented here is also contained in a separate paper by the author (*32*).

4.1 Introduction

This chapter addresses the concept of *driver lane choice* with regards to an ATL approach. Intuitively, each approaching driver intending to pass through the intersection uses the lane which he or she believes will save him or herself the greater amount of travel time while maintaining a desired level of comfort. Thus, the tradeoff between using the ATL and the CTL is essentially the travel time saved by using the ATL versus the inconvenience or risk of merging back into the CTL downstream of the intersection. The focus of this work is to explain the percentage of through-movement vehicles that use the ATL to clear the intersection, also known as the *ATL utilization*. Previous studies have developed models that purport to explain either this utilization or the raw through-movement flow in the ATL, but most of these studies have relied on data aggregated over one or more signal cycles to develop predictive statistical models (Chapter 3). Although these methods may successfully predict the flow in either lane based upon elements such as through-movement congestion and total hourly demand, they do not address the motivation for each driver to use either lane based on the set of conditions faced when approaching the intersection.

The motivation behind this research concerns the lane change algorithms of microsimulation systems such as VISSIM and CORSIM, which currently do not take into account the utility of either lane for each approaching vehicle. Instead, these systems use a combination of voluntary and mandatory lane changes, which are based on vehicle routing decisions and car following models (Chapters 1 and 2). The lane choice models presented in this research are designed specifically for implementation into these systems in order to make them more consistent with field observation at ATL approaches.

4.1.1 Research Objective

This chapter describes the development of behavioral model for driver lane choice at a signalized intersection with an ATL and one CTL. The principal objective is to gain an understanding of the factors influencing each driver's lane choice when approaching the intersection so that these factors can be implemented into the lane choice models in microsimulation systems. The remainder of this chapter is organized as follows: methodology, results, and conclusion.

4.2 Disaggregate Model Development Method

This section describes the methodology used to develop the disaggregate model for ATL lane use, including a discussion of the sites selected for model calibration and validation, the regression method, and the validation method.

4.2.1 Site Selection

The field data used to develop the driver lane choice model was extracted from a pool of video-recorded sites listed in Table 1-1. However, only 1-CTL sites were considered, and the author selected the sites with the best camera views (specifically, a view of the entire upstream and downstream portions of the ATL) for the calibration of the disaggregate model. This subset of the sites is described in Table 4-1. Figure 4-1 visually describes the sites by plotting the ATL utilization for each site, broken down by arrival phase. In both Table 4-1 and Figure 4-1, the validation site (NC-54 at Fayetteville Road) is marked with an asterisk (*).

TABLE 4-1. Summary of Sites Used in Disaggregate Model Calibration/Validation

Site #	Approach	Location	# Arrivals in Red		# Arrivals in Green		ATL Utilization
			CTL	ATL	CTL	ATL	
1*	EB NC 54 at Fayetteville Rd	Durham, NC	326	102	52	16	23.8%
2	NB Garrett Rd at Old Chapel Hill Rd	Durham, NC	185	51	62	13	20.6%
3	SB Garrett Rd at Old Chapel Hill Rd	Durham, NC	181	56	46	10	22.5%
4	EB Magee Rd at La Canada Dr	Tucson, AZ	280	56	40	19	19.0%
5	WB Magee Rd at La Canada Dr	Tucson, AZ	260	47	67	12	15.3%
6	NB La Canada Dr at Magee Rd	Tucson, AZ	312	66	176	33	16.9%
7	SB La Canada Dr at Magee Rd	Tucson, AZ	233	64	263	49	18.6%
8	EB Walker Rd at 185th St	Beaverton, OR	155	90	36	22	37.0%
9	WB Walker Rd at Murray Rd	Beaverton, OR	219	81	42	17	27.3%
Total			2,151	613	784	191	21.5%

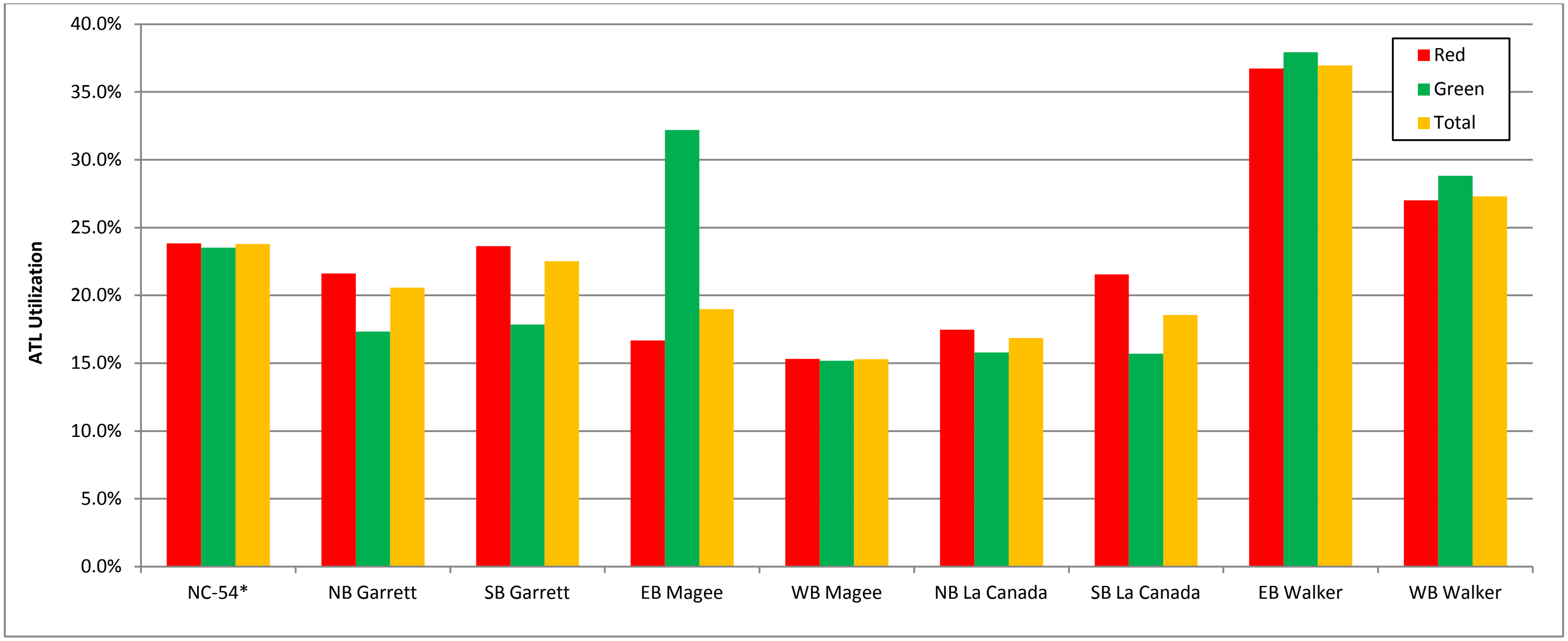


FIGURE 4-1. ATL Utilization by Site / Arrival Phase

The table lists the number of data points (vehicles) from video, broken down by arrival phase (red or green) and lane choice. The table indicates that approximately 21.5 percent of all vehicles used the ATL, but most vehicles (73.9 percent) arrived during the red phase. Although the number of arrivals in green that chose the ATL is small for most sites, the total number of observations is sufficiently large (191 vehicles) when all sites are combined. The first site, NC-54 at Fayetteville Road, was reserved for validation purposes and not used in the initial model calibration. This site was selected because it not only had the largest sample size but also exhibited a moderate level of ATL use. Although the cameras used to record the data at sites were positioned far away from the intersection to examine the maximum queue during each cycle, it was critical to choose a fixed distance upstream of the stop bar to measure some elements such as vehicle arrival time. Assuming that a free-flow travel time of six seconds from the decision point to the intersection is sufficient, the author recommended that the decision point should be positioned 300 to 500 feet upstream of the intersection based on the posted speed limit, which varied from 35 to 45 mph at each site. Every arriving vehicle during a 1.5 to 2 hour peak period was observed at each site, for a total calibration sample size of 511 vehicles.

4.2.2 Data Collection and Extraction

The following data were extracted from video for each arriving vehicle at the decision point:

- Lane choice (ATL or CTL),
- Vehicle type (passenger car or heavy vehicle),
- Signal indication (effective red or effective green) at time of arrival,
- Arrival time after start of red / start of green,
- Queue in each lane (a vehicle was considered queued if it was behind the stop bar),
- Queue difference, defined as the ATL queue length subtracted from the CTL queue length,
- Number of heavy vehicles queued in each lane,

- Time to clear intersection, defined as the difference between the maximum green time (for arrivals in red) or green time remaining (for arrivals in green) *g* and the product of the saturation headway *h* and CTL queue:

  Time to clear intersection = g – h*q (4-1)

- Movement (ATL choice or captive user). A captive user was defined as a vehicle that used the ATL to either turn right at the intersection (from a shared lane) or downstream of the intersection (into a driveway). Thus, these users were forced into the ATL by their turning movement and did not choose for the reasoning described in earlier sections of this paper. Although these observations were recorded for purposes of completeness (and to count them in the queue for a subsequently-arriving vehicle), they were removed from the dataset prior to model development.

4.2.3 Model Development and Validation

A discrete choice model is a common approach to modeling driver behavior, particularly when the analyzed behavior involves a small number of known responses—lane choice being a primary example. The reader is referred back to Section 2.3.4 for a discussion of discrete choice models. The author used the logit model form in Equation 2-10 to model the probability of ATL use for each driver as a function of covariates listed in Table 4-2.

TABLE 4-2. Covariates Used in Model Development

Covariate	**Unit**
CTL queue length	vehicles
ATL queue length	vehicles
Queue difference (CTL queue - ATL queue)	vehicles
Arrival time after beginning of red	seconds
Arrival time after beginning of green	seconds
Number of trucks in CTL	vehicles
Number of trucks in ATL	vehicles
Green time remaining	seconds
Time to Clear Intersection	seconds

The last term listed above, time to clear intersection, is the difference in the remaining green time and the product of the saturation headway (assumed to be two seconds) and the CTL queue length. This covariate was used to represent the amount of available green time *after* the CTL queue in front of the arriving vehicle discharges. Thus, a negative time to clear intersection would imply that the vehicle would be stopped at the intersection if it chose the CTL.

SAS logistic regression was used to develop several models for each site using the 0.05 significance level for each term, and the data were initially separated by arrival phase (either red or green) because the author hypothesized that the factors that influenced each driver's lane choice would depend on the phase (*31*). After a consistent group of site-by-site models was developed, the authors proceeded to combine the data at different levels (e.g. over all sites / red and green combined). To test whether the sites were significantly different (i.e. whether the combined model was statistically the same as the individual models), the likelihood ratio test statistic was conducted with

$$G^2 = -2(\mathrm{l}_{\mathrm{full}} - \mathrm{l}_{\mathrm{red}}) \qquad (4\text{-}2)$$

where G^2 follows a χ^2 distribution with degrees of freedom equal to one less than the number of sites used in the combined model; this is equivalent to the number of dummy variables necessary to model the effects of each site in Equation 2-10. l_{full} and l_{red} are the log-likelihood values of the full (with site effect) and reduced (without site effect) models, respectively (*24*). Because there were relatively few ATL observations in the dataset (approximately 20 percent), and the estimated probability that any driver will use the ATL is assumed to be low, the author also considered oversampling bias in the study. Although similar behavioral studies often oversample the “success” event (ATL use in this case) and must correct the resulting models for the bias, the sampling scheme of this study—specifically, sampling every arriving vehicle over a consistent interval at each site—avoids that issue (*24*).

The resulting models were then compared with the validation site, NC-54 at Fayetteville Road, by first computing the probability that each vehicle in the validation dataset used the ATL. Then the author computed the expected number of ATL users (under each model) and compared these with the actual number of users to explore model accuracy. The author also explored the precision of the models by aggregating the resulting probabilities into bins and then calculating the percentage of ATL users for each bin in hopes of finding an increasing trend.

4.2.4 Potential Sources of Error

The modeling exercise described in this section is built upon several assumptions that could lend some error to the results. The following is a list of some of the error that could occur if this methodology is undertaken:

- Assumptions of the logit model, including model form, independence of errors, explanatory variables, and lack of ordering. These are described in Section 2.3.2.
- Measurement error. Since the data are manually extracted, it is possible for some data points to be incorrectly recorded. However, due to the large sample size, it is likely that

such error will be negligible as long as the data are extracted consistently. In particular, the analyst must take care in keeping fixed points for the measurement of arrival times.

- Restricted access to either lane. Blockage of the CTL or ATL may occur due to queues extending beyond the ATL storage length on an approach. Since this event may alter a driver's lane choice, it must be considered when implementing the model at a site where blockage may occur. No blockage events occurred in the data used for this study.
- Uniform makeup of drivers throughout the observation period and between sites. The study assumes that drivers are predominately commuters and equally motivated to use the ATL if it has more utility.

With these assumptions in mind, it is likely that the set of models developed will be valid as long as the sample size is high and the data are extracted carefully.

4.3 Disaggregate Model Results

Table 4-3 lists the models for the arrivals in red for each site, as well as for all sites combined. Each row in the table is a separate model, and each model (with the exception of those labeled "Combined") contains only the data points from that site. These models were chosen as the best from a wide range of models that included all covariates. Statistically significant covariates ($p < 0.05$) are listed in the table. Several models (e.g. R1, R2, R3) were developed for each site. The table lists the coefficient for each parameter in the model, as well as the goodness-of-fit parameter, Gamma (estimated by the ratio of the difference of concordant and discordant pairs to their sum. The number of asterisks (*) next to each parameter indicates the p-value for testing the null hypothesis that the parameter is zero. All queues are measured in number of vehicles, and the queue difference is defined as the difference between the CTL and ATL queues. Finally, the parameter interpretation is

$$P(y = 1) = \frac{e^{\alpha+\beta x}}{1+e^{\alpha+\beta x}} \qquad (4\text{-}3)$$

where

$P(y = 1)$ is the probability that a vehicle will use the ATL,

α is the intercept term (the base utility of the ATL),

$\boldsymbol{\beta}$ is the vector of parameters (e.g. CTL queue, ATL queue, etc.), and

$\mathbf{x}$ is the covariate vector.

Thus, for continuous variables, the parameter value reflects the difference in log-odds for ATL use given a one-unit increase in the variable, assuming all other variables are held constant. Table 4-3 indicates that the parameter values were surprisingly consistent from site to site, and each reflected that there was some base disutility to using the ATL, as indicated by the negative value of the intercept. The signs of the parameter coefficients indicate that a vehicle will be more likely to use the ATL as the length of the CTL queue increases and the length of the ATL queue decreases. For example, in the model for NB Garrett Road R2, the parameter values indicate that for each increase of one vehicle in the CTL queue, the odds of using the ATL would increase by $e^{0.25}$, or 48 percent, while each increase of one vehicle in the ATL queue would lead to a decrease in odds of using the ATL by $e^{-0.46}$, or 37 percent. The values of gamma are not high—this indicates that there may be other variables that influence each driver's lane choice, although it may not be possible to account for all of these (e.g. random changes in human behavior). For each site, the third model form (R13, R23, etc.) tends to perform the best in terms of goodness of fit (gamma) and simplicity (queue difference is the only explanatory variable). Although this model form uses the queue difference to explain driver lane choice instead of accounting for the CTL and ATL queues separately, the author was confident in this relationship because of the goodness of fit and the tendency of the queue difference term to be much more significant ($p < 0.001$) than the CTL and ATL queue terms independently.

TABLE 4-3. Arrivals in Red Results

#	Site	Model	Intercept	CTL Queue	ATL Queue	Queue Difference	Gamma
1	NB Garrett	R11	-1.83***	0.17*			0.292
		R12	-1.80***	0.25**	-0.46*		0.377
		R13	-1.89***			0.24**	0.382
2	SB Garrett	R21	-1.73***	0.17**			0.289
		R22	-1.80***	0.25**	-0.46*		0.377
		R23	-1.90***			0.29***	0.363
3	WB Magee	R31	-2.11***	0.09			0.228
		R32	-2.00***	0.19**	-0.29**		0.365
		R33	-2.19***			0.19**	0.373
4	EB Magee	R41	-2.38***	0.16***			0.337
		R42	-2.41***	0.23**	-0.29		0.333
		R43	-2.43***			0.23***	0.359
5	EB Walker at 185	R51	-1.00***	0.17*			0.261
		R52	-1.09***	0.43***	-0.46**		0.324
		R53	-1.13***			0.43***	0.384
6	WB Walker at Murray	R61	-1.86***	0.10***			0.289
		R62	-1.85***	0.15***	-0.11		0.317
		R63	-1.69***			0.16***	0.330
7	NB La Canada	R71	-1.87***	0.07			0.180
		R72	-1.81***	0.09*	-0.13		0.220
		R73	-1.85***			0.09*	0.231
8	SB La Canada	R81	-1.80***	0.15**			0.289
		R82	-1.74***	0.24**	-0.30		0.286
		R83	-1.79***			0.24**	0.327
Combined		**R1**	-1.66***	0.09***			0.224
		R2	-1.67***	0.14***	-0.14***		0.281
		R3	-1.67***			0.14***	0.281
p-value: *<0.05 **<0.01 ***<0.001							

It was more difficult to explain the lane choice of each driver who arrived during the green phase. In this case, the amount of green time remaining in the cycle (using the maximum green in the signal plan for the subject approach) was used in model development. The results are displayed in Table 4-4.

TABLE 4-4. Arrivals in Green Results

#	Site	Model	Intercept	Green Time Remaining	CTL Queue	ATL Queue	Gamma
1	NB Garrett	G11	-8.28**		0.63**		0.561
		G12	-3.95***		0.72***	-1.33**	0.728
		G13	-3.71***	0.10*			0.431
2	SB Garrett	G21	-2.00***		0.12		0.295
		G22	-2.00***		0.11	0.04	0.268
		G23	-1.19	-0.02			0.224
3	WB Magee	G31	-1.96***		0.05		0.175
		G32	-1.90***		0.07	-0.11	0.132
		G33	-2.84**	0.06			0.357
4	EB Magee	G41	-0.56		-0.03		0.051
		G42	-0.50		-0.06	0.11	0.071
		G43	-0.84	0.01			0.000
5	EB Walker at 185	G51	-1.23**		0.26*		0.432
		G52	-1.40**		0.54*	-0.44	0.427
		G53	-1.44*	0.07			0.395
6	WB Walker at Murray	G61	-1.40*		0.04		0.266
		G62	-1.44*		0.07	-0.05	0.294
		G63	-2.14*	0.06			0.232
7	NB La Canada	G71	-2.12***		0.10*		0.296
		G72	-2.09***		0.15**	-0.30	0.317
		G73	-1.78***	0.01			0.043
8	SB La Canada	G81	-2.41***		0.38***		0.397
		G82	-2.38***		0.44***	-0.20	0.356
		G83	-2.70***	0.04***			0.284
Combined		**G1**	-1.81***		0.09***		0.305
		G2	-1.84***		0.13***	-0.10*	0.304
		G3	-1.83***	0.02*			0.107
p-value: *<0.05 **<0.01 ***<0.001							

The models in Table 4-4 indicate that the CTL queue is the leading factor in determining whether a driver who arrives during the green phase will use the ATL. Although the disutility of the ATL is higher during the green phase (indicated by an intercept of -1.8 compared to

-1.6 during the red phase), drivers are no longer as concerned about the queue in the ATL as opposed to the CTL. However, the absence of the ATL queue as a significant term in any of the models may stem from the observation that most of the ATL users were discharged shortly into the green phase, making the ATL queue disappear for most of these arrivals. The coefficient of 0.02 for the green time remaining in the combined model G3 indicates that the ATL becomes less favorable as the green time elapses—this is counterintuitive to the hypotheses in Chapter 1, but due to the low sample size of vehicles arriving late in the green phase, the relationship between arrival time (outside of arrival phase) and ATL utility is inconclusive. Likewise, note that the green time remaining parameter failed to be significant ($p < 0.05$) in many of the site models. The author prefers the first model form (G11, G21, etc.) because it had nearly the same goodness of fit as the second model form but explained much of the data variability using only one term (CTL queue).

The author then combined the arrivals in red and green to create a larger dataset—Table 4-5 displays these models. Note that a new variable, time to clear intersection, has been included in the models—this variable was also considered in the individual red/green models but was not significant to any of the models.

TABLE 4-5. Combined Arrivals Results

#	Site	Model	Intercept	CTL Queue	ATL Queue	Time to Clear Intersection	Gamma
1	NB Garrett	C11	-1.86***	0.13**			0.266
		C12	-1.97***	0.32***	-0.70***		0.425
		C13	-1.11*			-0.01	0.133
2	SB Garrett	C21	-1.72***	0.14**			0.270
		C22	-1.74***	0.23***	-0.34*		0.297
		C23	-0.60			-0.02	0.172
3	EB Magee	C31	-2.10***	0.14**			0.290
		C32	-2.13***	0.20***	-0.25		0.300
		C33	-0.38			-0.06***	0.330
4	EB Walker at 185	C41	-1.05***	0.19**			0.304
		C42	-1.16***	0.46***	-0.46***		0.399
		C43	0.04			-0.02	0.169
5	WB Walker at Murray	C51	-1.72***	0.08***			0.283
		C52	-1.75***	0.13***	-0.10		0.313
		C53	-0.66***			-0.03**	0.244
6	WB Magee	C61	-2.07***	0.08			0.215
		C62	-1.96***	0.14**	-0.22*		0.315
		C63	-1.52***			-0.01	0.125
7	NB La Canada	C71	-1.97***	0.08**			0.229
		C72	-1.91***	0.11***	-0.17		0.250
		C73	-1.13***			-0.02	0.115
8	SB La Canada	C81	-2.08***	0.23***			0.391
		C82	-2.04***	0.30***	-0.26*		0.361
		C83	-1.80***			0.01	0.092
Combined		**C1**	-1.70***	0.09***			0.252
		C2	-1.72***	0.14***	-0.12***		0.272
		C3	-2.03***			0.01*	0.228
p-value: *<0.05 **<0.01 ***<0.001							

Again the models indicate that the CTL queue is the principal variable that influences each lane choice, with several models including a (nearly equal but opposite) term for ATL queue as well. Together with the base disutility of the ATL (indicated by the negative value of the intercept), this indicates that it may take several more queued vehicles in the CTL than the ATL to increase the probability of choosing the ATL. The variable time to clear intersection was not significant to many of the site models, likely for the same reasons that the green time remaining was not significant (discussed following Table 4-4). The positive coefficient (0.01) for the time to clear intersection is also counterintuitive, as this would reflect that the utility of the ATL increases as the time left after the CTL queue clears increases. The preferred model form in this case is the second model for each site (C12, C22, etc.) because of the high goodness of fit. The fact that this model form considers the CTL and ATL queues independently reflects the combined dataset (and a compromise between the preferred model forms for the red and green models separately).

The author also tested for site variability by computing the likelihood ratio statistic in Equation 4-1 for each of the nine **Combined** models. The results are presented in Table 4-6, which lists each model from Tables 4-3 through 4-5, the likelihood ratio statistic and p-value, as well as which sites in the model contributed positively or negatively (the site numbers are listed in Table 1). Site 9 was used as a reference for the site effect.

TABLE 4-6. Comparison of Combined Models with and without Site Effect

Combined Model	G^2	Degrees of Freedom	p-value	positive sites with p<.05	negative sites with p<.05
R1	64.8	7	<0.001	8	4, 5, 6
R2	75.2	6	<0.001	2	1, 4
R3	75.0	7	<0.001	8	4, 5, 6
G1	22.9	7	0.002	8	
G2	24.7	6	<0.001	8	6
G3	34.5	7	<0.001	4, 8	6, 7
C1	77.4	7	<0.001	8	5, 6
C2	91.5	6	<0.001	8	4, 5, 6
C3	77.7	7	<0.001	8	5, 6

The table indicates that the site effect is significant for each model, and that site 8 tends to contribute positively to the utility of the ATL. The Tucson sites (4 through 7) tended to contribute negatively. Although these results indicate that much of the variability in the data may be caused by site-by-site factors (specifically location), for purposes of widespread model applicability, it may not be possible for the author to specify a correction for site location. A more in-depth analysis of the site-by-site variability is contained in Appendix D.

4.4 Model Validation

To test for model accuracy, each of the nine **Combined** models in Tables 2 through 4 was used to predict the probability of ATL use for each driver in the validation dataset (NC-54 at Fayetteville Road). Table 4-7 lists the expected number of ATL users predicted by each model, and Figure 4-2 provides a visualization of the accuracy of the models. Table 4-7 also displays the Brier Score, which ranges from zero to one and is calculated as

$$B = \frac{1}{N}\sum_{t=1}^{N}(f_t - o_t)^2 \tag{4-4}$$

where

N = number of observations,

t = tth observation,

f_t = forecasted probability for the tth observation, and

o_t = outcome of the tth observation (zero or one).

The Brier Score yields another way to compare the models based on their accuracy, where a lower score corresponds to a more accurate model (*33*).

TABLE 4-7. Model Results versus Actual Data for Validation Site

Model	R1	R2	R3	G1	G2	G3	C1	C2	C3
Model Expected # ATL Users	85	87	87	13	13	12	96	98	90
Actual # ATL Users	102	102	102	16	16	16	118	118	118
% Error	17	15	14	18	17	26	18	17	24
Brier Score	0.180	0.178	0.178	0.180	0.180	0.183	0.181	0.179	0.182

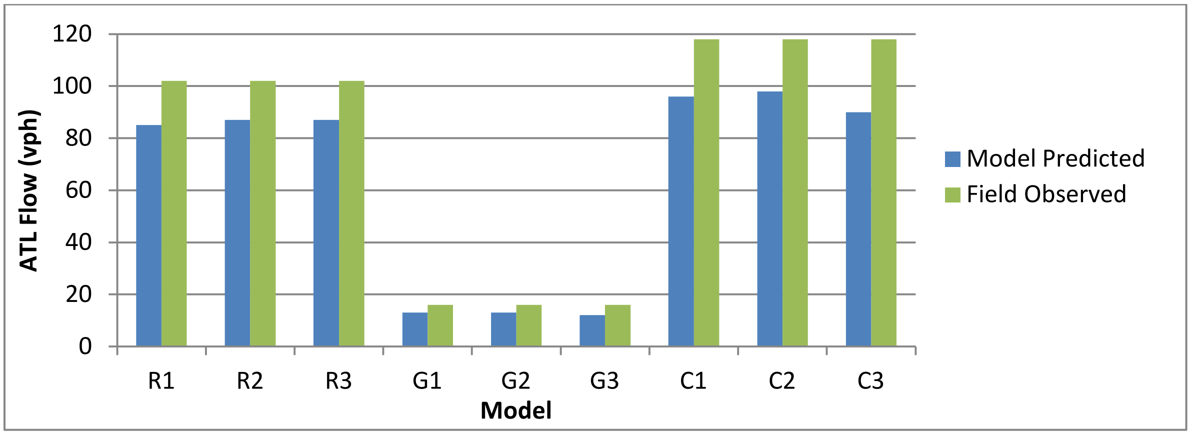


FIGURE 4-2. Model Accuracy

The results of the comparison in Table 4-7 indicate that none of the models were able to achieve an outstanding level of accuracy when compared to the validation data, but the models were still able to account for a large portion of ATL use. Note that each of the models under-predicted the number of ATL users from the field—this may be due to some systematic bias in the disaggregate model. The validation site, alternatively, exhibited a moderate but slightly higher level of ATL use when compared with the calibration sites (23.5 percent compared with 21.2 percent). The fact that the validation site is an exclusive ATL may have contributed to the tendency of the models to under predict the ATL flow for that site. Bias aside, if the greatest level of accuracy is desired, the author recommends using either model R2 with model G2 or the combined red/green model C2.

To investigate model precision, the author calculated the proportion of ATL users at each level of model-predicted probability for the validation site. This can best be explained by the following steps:

1. Use the disaggregate models to calculate the probability of ATL use for each vehicle in the validation dataset.
2. Based upon these calculated probabilities, group these vehicles into bins of width 0.05.
3. Determine the percentage of vehicles in each bin that actually used the ATL (i.e. the ATL utilization).

These results are listed in Table 4-8, which lists the percentage of drivers in the validation dataset that used the ATL at each level of model-predicted probability. Ideally, the higher the predicted probability, the greater the level of ATL use.

TABLE 4-8. ATL Utilization at Each Predicted Probability of ATL Use

Probability Bounds		**Combined Models**								
Lower	Upper	R1	R2	R3	G1	G2	G3	C1	C2	C3
10%	15%	--	--	--	6.3%	6.3%	--	--	--	15.6%
15%	20%	19.9%	20.8%	20.8%	40.0%	35.0%	23.9%	19.7%	20.8%	21.9%
20%	25%	29.6%	27.4%	27.4%	24.1%	29.4%	--	29.1%	27.9%	33.9%
25%	30%	32.0%	48.1%	48.1%	28.6%	11.1%	--	30.8%	36.4%	26.3%
30%	35%	66.7%	18.2%	18.2%	--	40.0%	--	50.0%	12.5%	100.0%
35%	40%	--	26.7%	--	--	--	--	--	57.1%	--
40%	45%	--	--	100.0%	--	--	--	--	--	--
Sample Size (veh)		429	429	429	67	67	67	496	496	496

The results in Table 4-8 indicate that each of the models yielded a reasonable level of precision, as the ATL utilization tended to increase with increasing model-predicted probability. The greatest level of precision (i.e. a strictly increasing trend) was exhibited by models R1 and C1. It is also interesting to note that while none of the models generated a probability of ATL use above 0.5 for any vehicle, the range of predicted probabilities is consistent with the range of observed average ATL utilization in the field, which tends to be between 10 and 40 percent (Table 1). Thus, the models appear to map each observation onto this range, with arrival phase, queue lengths, etc. contributing to a higher or lower probability of using the ATL.

4.5 Summary of Disaggregate Models

The results presented in Tables 4-2 through 4-4 indicate that when the logit form is assumed, driver lane choice is principally a function of arrival phase and the queues in either lane. This corresponds to an intuitive thought process—as a particular driver reaches the decision point, he or she checks the signal indication and the queues before choosing either lane. The low values of gamma (below 0.4) indicate that much of the variability in the site-by-site data may be triggered by other events (e.g. local driver behavior or aggressiveness, land use, etc.), while the variability in the combined datasets may be triggered by differences in utility from site to site. Finally, much of the data variability may simply be due to unexplained human behavior.

The results of the validation exercise indicate that while the models were not extremely accurate at predicting which vehicles would use the ATL, the models were precise in that higher predicted probabilities corresponded with greater levels of ATL use. Based on the goodness-of-fit of the calibrated models and the validation results, the author recommends using either the arrivals on red model R3 in combination with the arrivals on green model G1 or the combined model C2. The simplicity of the models and previous efforts noted in the literature suggest that these models may easily be implemented in the voluntary lane change algorithms of microsimulation systems in order to improve their ability to predict ATL use—in effect, the form of the models indicates that, based upon a random number draw, the simulation system would assign each arriving vehicle to either lane according to the model predicted probability. Such a system could use either a pair of the models for either arrivals on red or green or one of the combined models, if appropriate. A further discussion of this implementation is contained in Section 6.2.8.

5 MODEL COMPARISON

This chapter contains a comparison of the aggregate and disaggregate models for ATL lane use. The aggregate models described in Chapter 3 predicted the ATL flow rate as a function of macroscopic elements, such as through-movement demand and signal timing. Alternatively, the disaggregate models described in Chapter 4 use an event-based approach to predict each arriving driver's lane choice. In this chapter, the author investigates how this disaggregate model compares with the previously-developed aggregate model. This chapter presents a simulation algorithm to demonstrate the disaggregate model and its application in microsimulation systems using a random number generator. The algorithm is also used to achieve an appropriate comparison between the aggregate and disaggregate models by generating the predicted ATL flow under each model. This research is also contained in a separate paper by the author (*34*).

This chapter is organized as follows: research objective, literature review, methodology, results, and conclusion. First, the author will describe the objectives of the study and then outline the literature relating to the research. Then the author will describe the methods used to develop each model and the comparison technique. Finally, the author will present the results, the interpretation of the results, the sensitivity analysis, and the conclusion.

5.1 Research Objective

The objective of this research is to achieve an understanding of the factors that affect ATL flow and how best to represent them in a prediction model—whether as an aggregate model or a disaggregate model. The principal contribution here is the method used to compare the two model forms, which are fundamentally different (described in Section 2.3). The author will compare the models and then make recommendations based on either of two results:

1. If the aggregate model and disaggregate model are not significantly different when statistically compared, then the aggregate model is considered to be validated by the disaggregate model.

2. If the two models are statistically distinguishable, then the author will explore the differences between them and then specify the better model based on goodness of fit and universal applicability.

5.2 Summary of Aggregate and Disaggregate Models

Each of the models discussed in this chapter was generated from a pool of sites taken from across the United States. These sites and their locations are listed in Table 5-1. The table indicates the number of 15-minute intervals of video recorded at each site, the number of individual vehicles observed during the total period of observation, and the average through-movement volume, average right turn volume, average ATL utilization, and average right turns (expressed as a percentage of total through and right turn volume) observed during the period.

TABLE 5-1. Summary of Disaggregate Model Field Data

Site #	Approach	Location	# 15-min Data Points	# Vehicles Observed*	ATL Type	Average Through Volume (vph)	Average Right Turn Volume (vph)	Average ATL Utilization (%)	Average RT %*
1	WB Walker at Murray	Beaverton, OR	6	359	Shared	552	102	29	16.0
2	NB La Canada at Magee	Tucson, AZ	9	587	Shared	683	95	19	12.2
3	SB La Canada at Magee	Tucson, AZ	8	609	Shared	576	144	18	19.9
4	EB Magee at La Canada	Tucson, AZ	13	395	Shared	407	37	19	8.6
5	WB Magee at La Canada	Tucson, AZ	7	386	Shared	367	168	14	31.6
6	EB Walker at 185th	Beaverton, OR	8	303	Exclusive	424	245	40	36.5
7	NB Garrett at Old Chapel Hill	Durham, NC	9	311	Exclusive	270	466	19	62.5
8	SB Garrett at Old Chapel Hill	Durham, NC	5	293	Exclusive	257	89	23	25.3
*Expressed as a percentage of total through and right turn volume									

5.2.1 Aggregate Model Summary

The author used the sites listed in Table 5-1 to develop an aggregate model to predict the hourly flow in the ATL. Although Chapter 3 presents aggregate models that are similar to this model, the aggregate model presented in this current chapter is distinct from the previous models because it was generated from a smaller dataset of eight sites (Table 5-1) and only applies to 1-CTL sites. The motivation behind developing a new aggregate model is to yield an appropriate comparison with the disaggregate models described in Chapter 4, which were developed using this same (reduced) dataset because it contained sites equipped with video cameras to provide the author with an adequate view of the entire length of the ATL. The aggregate model is as follows:

$$ATL\ through\ flow = 31.8 + 105.9X_T^2 + 9.16\left(\frac{Through\ flow}{100}\right)^2 - 88.1X_R \tag{5-1}$$

where

ATL through flow = the 15-minute flow rate of through-movement vehicles in the ATL (vph),

X_T = the demand to capacity ratio of the through-movement, assuming no ATL is present,

Through flow = the total 15-minute flow rate of through-movement vehicles (vph), and

X_R = the demand to capacity ratio of the right-turn movement (equal to zero for an exclusive lane).

The author considered many other variables in the process to develop this model (Section 3.1.2), but the aggregate model in Equation 5-1 was satisfactory because it explained 85 percent of the variability in the data and all terms were statistically significant ($p < 0.001$). This model indicates that the through-movement flow in the ATL increases as congestion along the approach increases, with about 32 vph using the ATL—approximately one per cycle—regardless of the congestion level. However, the flow in a shared ATL will decrease dramatically as the number of right-turns increases. This model does not contain site-to-site design factors such as those contained in the design variable (Table 3-3), although these variables were considered in the model development process to account for site-to-site variation in driver behavior. The fact that this reduced model has a better R^2 than the models presented in Chapter 3 that were developed using the full dataset (85 percent versus 78 percent) is coincidental, as these sites were selected solely based on the camera positions and not the reduced variability in the data.

5.2.2 Disaggregate Model Summary

The aggregate model was relatively successful in predicting the flow in the ATL as a function of few macroscopic input variables. However, during field observation, the author noticed queuing patters (for example, at a given site the third or fourth vehicle arriving during red would choose the ATL) and other behaviors that led them to question each driver's motivation to choose the ATL (described in Chapter 1). The need to incorporate these trends into microsimulation systems, many of which must be calibrated to achieve the correct level of ATL use, also prompted the author to attempt to model lane choice at ATLs from a more fundamental perspective, particularly from the individual driver's point of view. To this effect, the author developed nine models to predict the probability of ATL use as a function of several event-based variables that were recorded at the time of the vehicle's arrival at a consistently-chosen decision point. The development of these models is discussed in Chapter 4.

Table 5-2 contains a summary of these disaggregate models, which reflect the utility of the ATL based on the conditions observed by each arriving driver. The model parameter coefficients listed in the table indicate how the utility of the ATL increases (as indicated by a positive sign) or decreases (as indicated by a negative sign) with each parameter. Intuitively, the probability that a driver will choose the ATL tends to increase as the CTL queue increases or as the difference between the lengths of the CTL and ATL queues increases—these trends are reflected in the models. Additionally, the author hypothesized that the motivation for drivers' lane choice would depend upon the signal phase (effective green or red) observed at the decision point—models R1, R2, and R3 are for arrivals in red, models

G1, G2, and G3 are for arrivals in green, and the remaining models are for all (combined) arrivals.

TABLE 5-2. Summary of Disaggregate Models

Model	Intercept	CTL Queue	ATL Queue	Queue Difference	Green Time Remaining	Time to Clear Intersection	Gamma
R1	-1.66	0.09					0.224
R2	-1.67	0.14	-0.14				0.281
*R3	-1.67			0.14			0.281
*G1	-1.81	0.09					0.305
G2	-1.84	0.13	-0.10				0.304
G3	-1.83				0.02		0.107
C1	-1.70	0.09					0.252
C2	-1.72	0.14	-0.12				0.272
C3	-2.03					0.01	0.228
*Selected to compare with aggregate model							

Although any of these models could be compared to the aggregate model using the methodology described in the following sections, the authors chose two models (R3 for arrivals in red and G1 for arrivals in green) to demonstrate these methods because they had the best fit and had few parameters.

The primary contribution of this chapter is to develop a method to compare the two types of models. The challenge is to use the same input data for each model type and then obtain comparable output data. As Table 5-3 indicates, each model form is built upon a separate set of assumptions and uses a different set of input data. While the aggregate model uses the through-movement hourly flow and signal timing to model the ATL hourly flow, the disaggregate model is a function of the events observed by each arriving vehicle. To address the issue of using macroscopic input data, such as hourly flows, with a discrete choice model, one can use the principles of stochastic queuing analysis (*35*). Under this approach, vehicle inter-arrival times can be assumed to be random and thus modeled using the exponential distribution, which has the following cdf:

$$F(t) = 1 - e^{-\lambda t} \tag{5-2}$$

where

t = inter-arrival time (s),

λ = arrival rate (in vehicles per second), and

F(t) = probability of observing an inter-arrival time less than or equal to t.

Using this assumption, one can use a given hourly traffic flow and break it down into individual vehicle arrival times with the aid of a second technique—the Monte Carlo simulation (*8*). Using a random number generated from a [0,1] distribution, one can invert the cdf in Equation 5-3 to obtain the following equation for arrival time:

$$t = \frac{-\ln(1-r)}{\lambda} \tag{5-3}$$

where *r* is the random number and *ln* is the natural logarithm. Although each observation between 0 and 1 is equally likely to be selected by the random number generator, these observations are transformed so that a random number near zero corresponds to a small inter-arrival time, and a random number near one yields a large inter-arrival time.

5.3 Model Comparison Methodology

The following sections describe the methods used by the authors to demonstrate and compare the two models.

5.3.1 Model Simulation

Figure 5-1 displays a flow chart of the proposed methodology to simulate the disaggregate model. Rather than working with individual vehicle data for both models, the author chose to begin with macroscopic input (e.g. hourly demand and signal timing by cycle) and then present the results from the disaggregate model in a comparable form. This was accomplished through Monte Carlo simulation using an Excel spreadsheet (*36*). First, the author assumed that vehicle headways could be modeled with an exponential distribution (*35*). Each arriving vehicle was represented by a row in the spreadsheet, and a random number r_1 was generated for each to determine the vehicle's arrival time after the previous vehicle (see Equation 5-3). Then a second random number r_2 was used to determine whether the vehicle was assigned to make a right turn or continue through the intersection based upon the input data. Then, assuming a fixed signal cycle, it was determined whether each through-movement vehicle arrived in effective red or effective green based on a look-up table of (fixed) signal timing attributes. The appropriate model was then chosen based upon the arrival phase, and the queues were calculated based on previous arrivals in the cycle. Each cycle was reset using the MOD (modular arithmetic) function in Excel with the cycle length as the divisor. Then, using the appropriate variables, the model generated the probability of ATL use for each driver, and a third random number r_3 was used to determine whether that vehicle chose the ATL. The spreadsheet also checked the queues for each arriving vehicle based on the number of vehicles that had discharged from either lane (determined by the arrival phase, saturation flow rate, and turning movement) since the previous arrival.

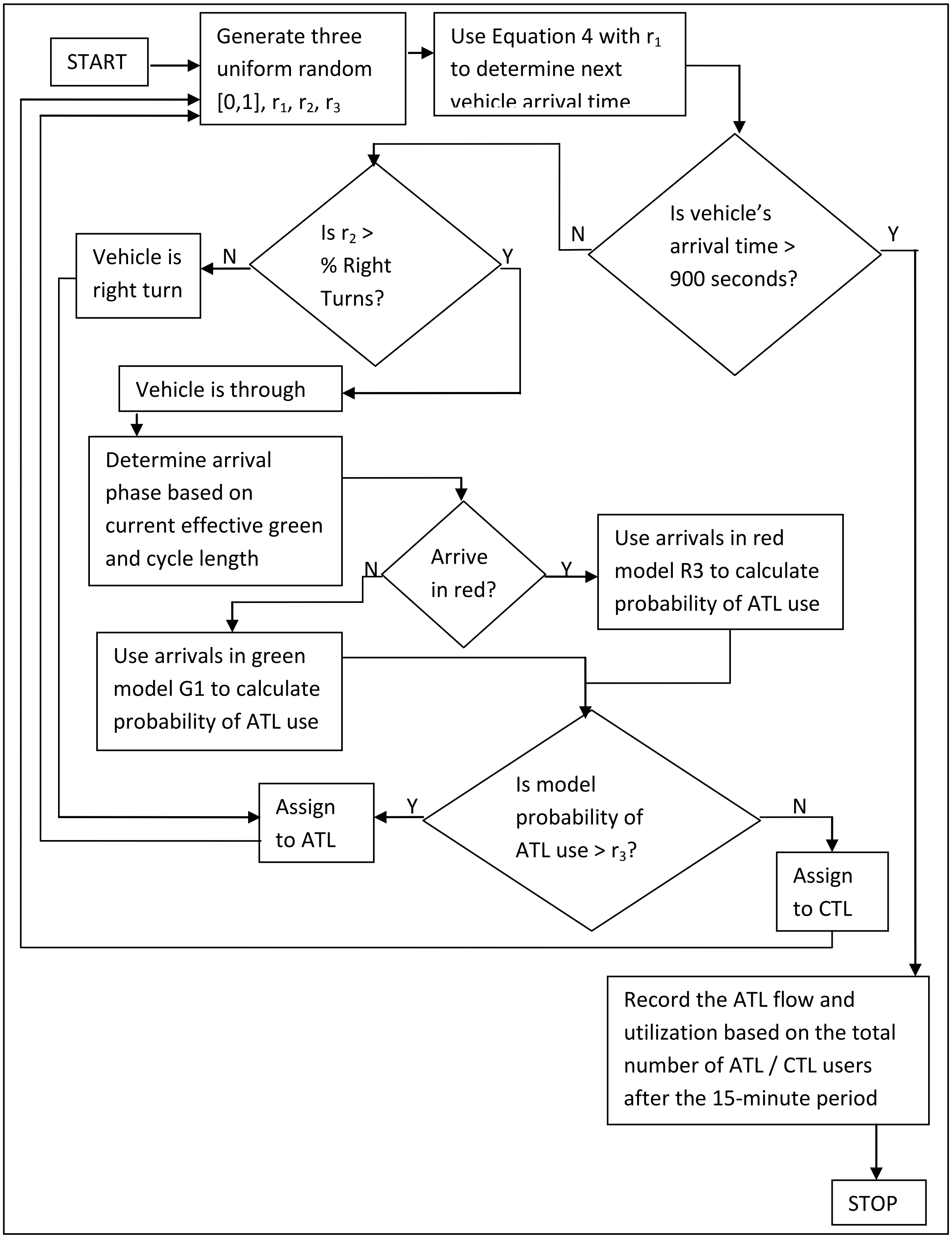
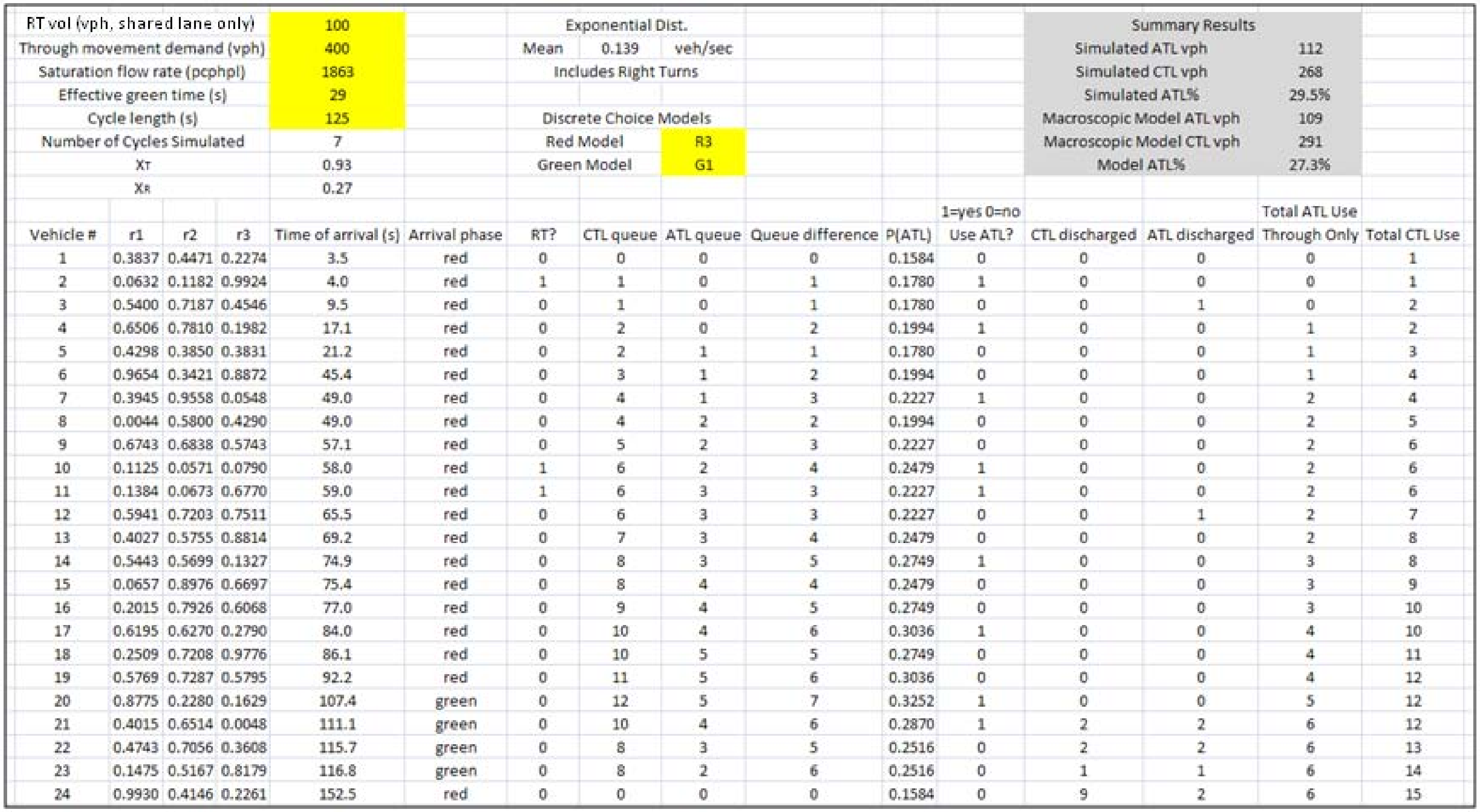


FIGURE 5-1. Flowchart of Disaggregate Model Representation in Simulation

After 15 minutes of simulation, the spreadsheet took the lane-by-lane counts from the last row and calculated the ATL hourly flow and utilization. Although the flow chart displays the methodology for a shared ATL, an exclusive ATL is simulated using similar methods, but with zero right turn demand. Consistent with conventional methodology regarding microsimulation, the author used multiple runs to mitigate variability caused by random number seeds. In this case, the author used the average of 50 simulation runs for each prediction.

Figure 5-2 displays a screenshot of the simulation tool with an example problem. The first vehicle in the example arrives at t=3.5 seconds, which is during the red phase. To check whether the vehicle makes a right turn, the spreadsheet uses the proportion of right turns to all through and right turn traffic and compares this number with the random number r_2. Since the random number (0.4471) is greater than this ratio (0.2), the vehicle does not make a right turn. Based on the discrete choice model R3 (see Table 5-2), the probability that this vehicle will use the ATL is 0.1584. Because this number is lower than the random number r_2 (0.45), the vehicle does not use the ATL. The following vehicle uses the ATL because it makes a right turn. The first through-movement vehicle to choose the ATL is vehicle #4, which has a probability of ATL use equal to 0.1994. This is greater than the random number r_3 (0.1982), so this vehicle uses the ATL. This process repeats until the end of the red phase (t = 96 seconds), when the CTL queue becomes high (12 vehicles). This long queue prompts the first two vehicles to arrive in green to choose the ATL. Since these vehicles arrive in green, the model G1 (see Table 5-2) takes over. Then two more vehicles arrive on green before the next cycle begins at t=125 seconds, and the process repeats. The last two columns record the cumulative CTL and ATL (through-movement only) use so that these numbers can be used to compute the hourly flow after t=900 seconds (15 minutes of simulation).



RT vol (vph, shared lane only)	100
Through movement demand (vph)	400
Saturation flow rate (pcphpl)	1863
Effective green time (s)	29
Cycle length (s)	125
Number of Cycles Simulated	7
X_T	0.93
X_R	0.27

Exponential Dist.

Mean 0.139 veh/sec

Includes Right Turns

Discrete Choice Models

Red Model	R3
Green Model	G1

Summary Results	
Simulated ATL vph	112
Simulated CTL vph	268
Simulated ATL%	29.5%
Macroscopic Model ATL vph	109
Macroscopic Model CTL vph	291
Model ATL%	27.3%

Vehicle #	r1	r2	r3	Time of arrival (s)	Arrival phase	RT?	CTL queue	ATL queue	Queue difference	P(ATL)	1=yes 0=no Use ATL?	CTL discharged	ATL discharged	Total ATL Use Through Only	Total CTL Use
1	0.3837	0.4471	0.2274	3.5	red	0	0	0	0	0.1584	0	0	0	0	1
2	0.0632	0.1182	0.9924	4.0	red	1	1	0	1	0.1780	1	0	0	0	1
3	0.5400	0.7187	0.4546	9.5	red	0	1	0	1	0.1780	0	0	1	0	2
4	0.6506	0.7810	0.1982	17.1	red	0	2	0	2	0.1994	1	0	0	1	2
5	0.4298	0.3850	0.3831	21.2	red	0	2	1	1	0.1780	0	0	0	1	3
6	0.9654	0.3421	0.8872	45.4	red	0	3	1	2	0.1994	0	0	0	1	4
7	0.3945	0.9558	0.0548	49.0	red	0	4	1	3	0.2227	1	0	0	2	4
8	0.0044	0.5800	0.4290	49.0	red	0	4	2	2	0.1994	0	0	0	2	5
9	0.6743	0.6838	0.5743	57.1	red	0	5	2	3	0.2227	0	0	0	2	6
10	0.1125	0.0571	0.0790	58.0	red	1	6	2	4	0.2479	1	0	0	2	6
11	0.1384	0.0673	0.6770	59.0	red	1	6	3	3	0.2227	1	0	0	2	6
12	0.5941	0.7203	0.7511	65.5	red	0	6	3	3	0.2227	0	0	1	2	7
13	0.4027	0.5755	0.8814	69.2	red	0	7	3	4	0.2479	0	0	0	2	8
14	0.5443	0.5699	0.1327	74.9	red	0	8	3	5	0.2749	1	0	0	3	8
15	0.0657	0.8976	0.6697	75.4	red	0	8	4	4	0.2479	0	0	0	3	9
16	0.2015	0.7926	0.6068	77.0	red	0	9	4	5	0.2749	0	0	0	3	10
17	0.6195	0.6270	0.2790	84.0	red	0	10	4	6	0.3036	1	0	0	4	10
18	0.2509	0.7208	0.9776	86.1	red	0	10	5	5	0.2749	0	0	0	4	11
19	0.5769	0.7287	0.5795	92.2	red	0	11	5	6	0.3036	0	0	0	4	12
20	0.8775	0.2280	0.1629	107.4	green	0	12	5	7	0.3252	1	0	0	5	12
21	0.4015	0.6514	0.0048	111.1	green	0	10	4	6	0.2870	1	2	2	6	12
22	0.4743	0.7056	0.3608	115.7	green	0	8	3	5	0.2516	0	2	2	6	13
23	0.1475	0.5167	0.8179	116.8	green	0	8	2	6	0.2516	0	1	1	6	14
24	0.9930	0.4146	0.2261	152.5	red	0	0	0	0	0.1584	0	9	2	6	15

FIGURE 5-2. Screenshot of Monte Carlo Simulation Tool

The author made several assumptions when using this method:

- First, the author assumed that each cycle could be represented as fixed-time, with all vehicles arriving at random (without platooning);
- Each cycle was modeled in terms of effective red and effective green only—although the author considered start-up lost time, the end gain was not considered because this tends to vary more widely from site to site;
- The author assumed a constant saturation headway—each through-movement vehicle would be discharged from the stop bar according to the saturation headway input by the user;
- All arriving vehicles were assumed to be passenger cars—equivalently, they each possessed the same saturation headway;
- Another assumption concerned right turns on red from a shared ATL. Although the saturation flow rate for right turns was adjusted to be consistent with the Highway Capacity Manual, the author assumed that during the red phase, the leading right-turning vehicle at the stop bar would be able to discharge from intersection (i.e. right turn on red) (*3*).

5.3.2 Statistical Comparison

Once the disaggregate model was simulated for 50 iterations using the algorithm described above, the averaged ATL flows from each set of iterations were compared with the aggregate model results (based on the input through-movement flow and signal timing over a 15-minute interval) using the paired t-test (*24*). The author compared the ATL flow predicted by each model and repeated the test for each 15-minute interval of field data in the database (using the actual through-movement demand, signal timing, and saturation flow rate recorded in the field), with the null hypothesis being that the average of the differences between the model estimates for each sample is zero. The test statistic is defined as

$$t = \frac{\overline{d}}{\sqrt{\frac{s^2}{n}}} \qquad (5\text{-}4)$$

where d-bar is the mean difference, s^2 is the sample variance, and n is the sample size (*24*). After this test statistic was computed, it was compared to the 95% confidence interval of the t-distribution using n–1 degrees of freedom. Unfortunately, the amount of video data collected at each site (five to ten 15-minute periods for each site, totaling 65 interval data points across all sites) may limit the power of the test to detect a significant difference in the data, but this exercise acts as some validation for the aggregate models and provides a methodology for the comparison of the two models.

5.4 Model Comparison Results

Table 5-3 displays the results of the model comparison—on average, the aggregate and disaggregate models predicted lower ATL flows than the field data, with the aggregate model predicting higher ATL flows than the disaggregate model. However, the table indicates that these differences are not statistically significant. The left two columns of Table 5-3 display the results of the disaggregate and aggregate model comparison based on a total of 65 15-minute intervals from the eight sites in the database (Table 1). The table indicates that the mean difference was 3.8 ATL vph, which indicates that, on average, the ATL flow rate predicted by the aggregate model was 3.8 vph greater than the flow predicted by the disaggregate model. This was not found to be a statistically significant difference at the 0.05 significance level, indicating that the models yielded statistically indistinguishable results.

TABLE 5-3. Comparison of Models and Field Data

H_0: Aggregate and Disaggregate Models (R3 / G1) are the same*		H_0: Disaggregate Model and Field Observations are the same*		H_0: Aggregate Model and Field Observations are the same*	
$\bar{d}$	3.8	$\bar{d}$	-3.8	$\bar{d}$	-0.006
s^2	408.7	s^2	830.7	s^2	396.3
n	65	n	65	n	65
test stat	1.50	test stat	1.05	test stat	0.002
df	64	df	64	df	64
p-value	0.138	p-value	0.295	p-value	0.998
result	Do not reject	result	Do not reject	result	Do not reject
power	0.085	power	0.180	power	0.129
*Avg. ATL Flow (vph) of all 65 15-min intervals: Field = 98.1, Aggregate = 98.1, Disaggregate = 94.3					

The author similarly compared the disaggregate model with the field data, shown in the middle two columns of Table 5-3. The mean difference indicates that, on average, the ATL flow rate observed in the field was 3.8 vph higher than the prediction of the disaggregate model—this was found to be not significant at the 0.05 significance level. Thus, the disaggregate model is validated by the field data. Finally, the right two columns of Table 5-3 display the test results for the comparison of the aggregate model to the field-observed data. Like the disaggregate model, this last comparison indicates that the aggregate model predictions are not significantly different from field observation; in fact, the mean difference was only 0.006. In each case, the achieved power to detect a difference in the means equal to the calculated d-bar is low, but the power is in fact greater than 75% if the difference increases to 10 ATL vph, which the author considers a reasonable threshold for comparison (note that this would require the significance level α to be lower). The reader may also be interested in the comparison if the absolute difference (rather than the algebraic difference) between values is used to conduct the t-test. The corresponding results are contained in Appendix E.

The author continued to investigate the similarity between the two models and between each model and the field data by observing a series of plots, shown in Figure 5-3.

Each plot contains the model-predicted or field-observed ATL flow for each 15-minute data point. The figure indicates that, in general:

1. The discrete choice model predictions matched the aggregate model predictions,
2. The discrete choice model predictions matched the field data, and
3. The aggregate model predictions matched the field data.

For each plot, the author calculated a regression line (indicated by the dashed line), recorded the R^2 value, and tested whether the intercept was statistically different from zero and whether the slope was statistically different from one. The results indicate a strong correlation for each comparison ($R^2 > 68\%$ in each case). However, each of the regression lines is statistically different from the 45-degree angle line shown in each plot, which indicates that there may be some difference in the model predictions as the level of ATL flow changes. In particular, the models appear more comparable (as shown by the first plot) and more accurate (as shown by the second and third plots) at low levels of ATL flow. This is likely because each of the sites in the comparison dataset (Table 5-1) exhibited an ATL flow of less than 200 vph. Given the fact that the average observed ATL utilization is typically 20 percent, this indicates that the model applicability may extend to sites with a total through-movement demand up to 1,000 vph, which is a wide range considering that each of the sites contains only one CTL. Table 5-4 displays a summary of the trend line for each plot, including the t-tests for whether the intercept is significantly different from zero and whether the slope is significantly different from one. The null hypothesis is rejected in all cases, indicating that there is some trend to the difference between the models and between the models and field data.

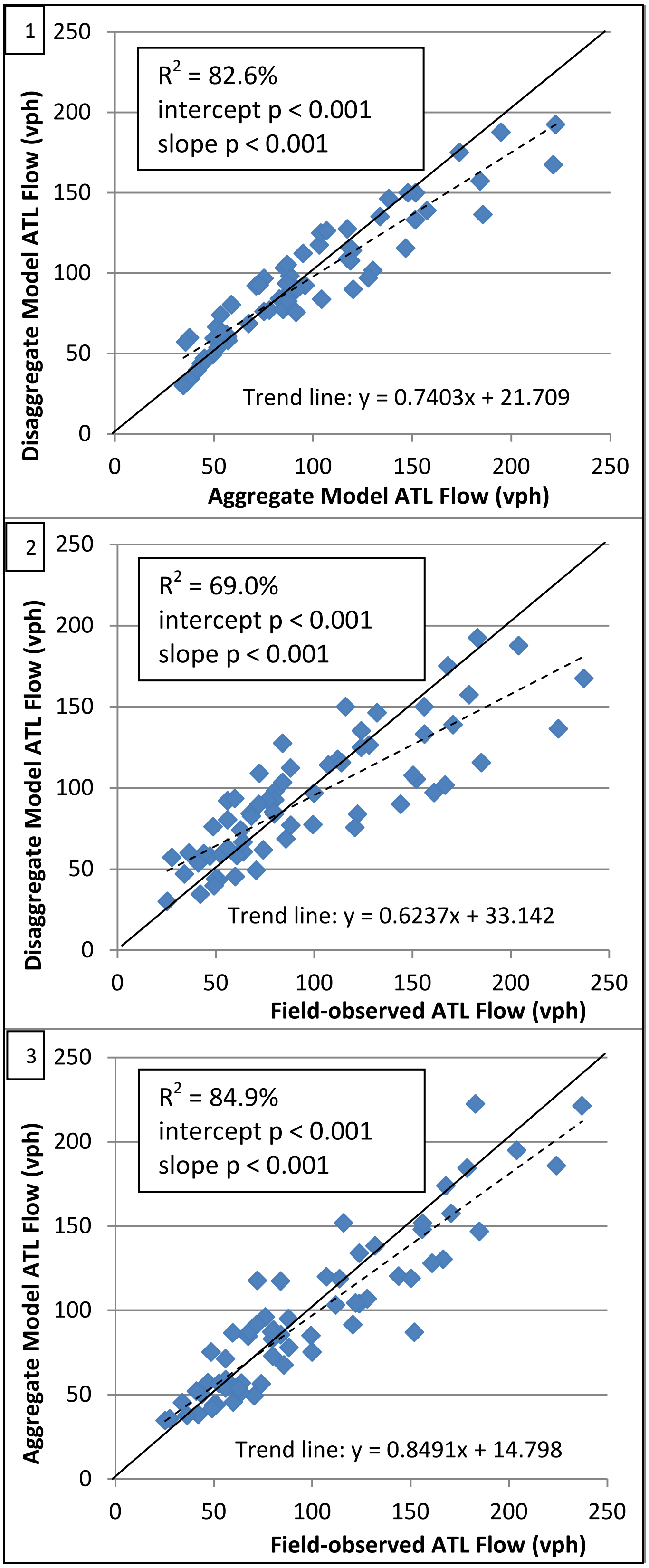


FIGURE 5-3. Comparison of Field Data with Model Predictions

TABLE 5-4. Trend Lines for Comparison of Field Data with Model Predictions

Line	R^2	Parameter	Estimate	Standard Error	H_0	t	p-value
Disaggregate vs Aggregate	0.83	Intercept	21.709	4.660	Intercept = 0	4.66	<0.001
		Slope	0.740	0.043	Slope = 1	6.05	<0.001
Disaggregate vs Field	0.69	Intercept	33.142	5.816	Intercept = 0	5.49	<0.001
		Slope	0.624	0.053	Slope = 1	7.09	<0.001
Aggregate vs Field	0.85	Intercept	14.798	4.982	Intercept = 0	5.49	<0.001
		Slope	0.849	0.045	Slope = 1	3.36	<0.001

5.4.1 Sensitivity Analysis

Although the results of the comparison indicate that the disaggregate model matched the aggregate model and the observed field data, the author wished to investigate any trends in the data that might affect the results. From this sensitivity analysis, it appeared that changes in X_T or through-movement demand did not appear to affect whether the models could predict accurate ATL flows when compared to each other or the field data—these plots are displayed in Appendix E. However, when right turn volume was varied, the models began to predict different results, as shown in Figure 5-4. The author used a constant level of 800 through-and right turn vph, saturation headway of 2 seconds/vehicle, and g/C = 0.35, and then the author varied the right turn volume. Although both models predicted lower ATL use as the number of right turns increased, the right turns had a more dramatic effect on the aggregate model. However, the models tended to predict comparable flows for moderate levels of right turns (150 to 250 vph, or about 20 to 30 percent of total through and right turn traffic).

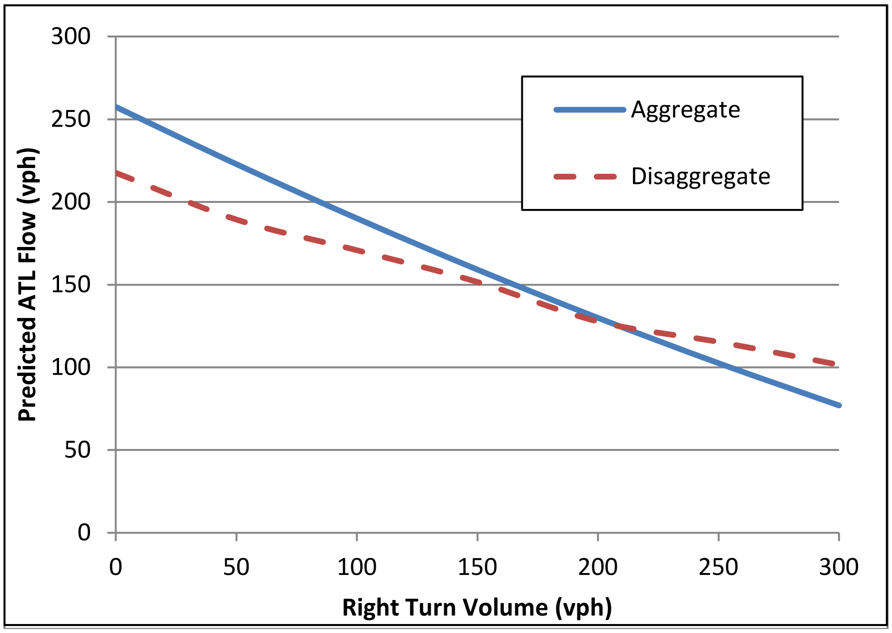


FIGURE 5-4. Comparison of Model-predicted ATL Flow with Right Turn Volume

5.5 Model Comparison Summary and Recommendations

The results of the comparison of the aggregate model for ATL through flow to the disaggregate model for lane choice at ATLs indicate that the models tend to predict similar levels of ATL flow for sites with only one CTL. The similarity of the model predictions when compared with each other and with the field data effectively validates the models (see objective 1). Given these results, the author recommends that either model be used based on the intent of the practitioner:

- If the intent is to predict the lane-by-lane flows at the intersection based upon a simple set of input data (through-movement demand, right turns, and signal timing), then the author recommends using the aggregate model.
- If the intent is to simulate the lane choice of a driver approaching the ATL, either in microsimulation or to investigate how changing certain operational elements (e.g. g/C or cycle length) would affect the queuing at the intersection (and, consequently, the lane-by-

lane flows), then the author recommends using the disaggregate model and possibly simulating the results using the methods described here.

The author successfully developed a method to achieve the comparison between the aggregate and disaggregate models by using the same input data and obtaining macroscopic output. The comparison methodology is simple and can easily be repeated for other models using a spreadsheet like the one presented here. The author recommends that the simulation methodology be updated to incorporate more challenging operational elements (such as actuated control) to more accurately model the characteristics of ATLs.

6 RESEARCH IMPLEMENTATION

This chapter describes how the models described in Chapters 3 and 4 can be implemented in current engineering practice. Regarding the aggregate models in Chapter 3, this chapter specifies how these models can be implemented in the Highway Capacity Manual (*3*). Later in this chapter the author discusses a methodology to incorporate ATL operations into microsimulation systems as well as how the disaggregate models described in Chapter 4 can be implemented into these systems.

6.1 Highway Capacity Manual Implementation

This section presents a method to incorporate the aggregate models into the signalized intersection procedure of the HCM. This procedure seamlessly fits into the current methodology and does not require additional input data. It adds detail and improves the sensitivity and applicability of the HCM methodology by providing an estimate of capacity and level of service for a signalized intersection approach where an ATL is present. This procedure was developed empirically and produces output that is analogous to the measures of effectiveness produced by the current HCM methodology. Specifically, the author addresses the following challenges with regard to implementing ATL operational models in the HCM methodology:

- Current lane groups and lane utilization factors f_{LU} should be updated to address the effect of an ATL.
- The ATL utilization prediction models are sensitive to signal timing, which implies that in the case of actuated control, equilibrium must be reached between the ATL flow and green time allocation.

These challenges are addressed in the remainder of this section, which is organized as follows: model summary, methodology, example problems, and conclusions. The research contained in this section is also contained in one of the author's published papers (*37*).

6.1.1 Model Summary

The author investigated the stimulus for drivers' ATL use by developing two empirical models to predict the flow in the ATL. One model was developed for ATL approaches with one CTL, while another was developed for approaches with two CTLs. Note that these models are slightly different from the models presented in Chapter 3 but that they still predict the ATL flow rate as a function of congestion and through-movement demand. The recommended models were developed to be compatible with current HCM Chapter 18 methodology by only requiring input data that would normally be applied in typical signalized intersection analyses (*3*). Although variables such as through flow, right turn flow, v/c ratio, and several design elements such as upstream, downstream, and total ATL length were considered in model development, the study determined that the chief stimulus for ATL use was through-movement congestion along the ATL approach. Congestion was accounted for using both total through-movement demand and X_T, the demand-to-capacity ratio of the through movement assuming no ATL presence. This term is thus sensitive to changes in signal timing that may vary from cycle to cycle. It was also found that right turns from a shared ATL may have an inhibiting effect on ATL use in some cases. The following model was developed for ATLs with one CTL (model 108 in Table 3-5):

$$ATL\ flow\ (vph) = 20.226 + 81.791X_T^2 + 1.65\left(\frac{Through\ flow}{100}\right)^2 \qquad (6\text{-}1)$$

where 15-minute flow rates are expressed in vehicles per hour (vph). The variable terms in this model were all highly significant ($p < 0.001$), and the model explained 78% of the variability in the 1-CTL data. A term-by-term analysis of the model suggests that X_T and through-movement flow heavily influence the flow in the ATL, which is intuitive, but approximately 20 vph will use the ATL regardless of the amount of congestion. Assuming an average cycle length of 120 seconds, this suggests that at least one vehicle will use the ATL during most cycles, which was consistent with field observation. Right-turns from a shared ATL, while intuitively inhibiting to ATL use, did not have a significant relationship to ATL use in the 1-CTL model. This is likely because nearly all of the study sites with high right turn flow were already provided with an exclusive right turn lane.

The 2-CTL model is described as follows (model 209 in Table 3-6):

$$ATL\ flow\ (vph) = 29.24 + 17.3\left(\frac{Through\ flow}{100}\right) - 90.291X_R \tag{6-2}$$

where

$$X_R = \frac{Right\ turn\ demand}{Right\ turn\ saturation\ flow\ rate \times g/C} \tag{6-3}$$

is the demand-to-capacity ratio for right-turns (set to zero for an exclusive right-turn lane). This model indicates a heavier effect of through-movement flow and is negatively affected by X_R. In this case, some of the study sites with shared ATLs *did* have inhibiting right turn flows. Note that this model excludes site 17 from Table 1-1 because the site had high through-movement demand but low ATL use—the author attributed this anomaly to the exceptionally high proportion of arrivals in green (and, consequently, very low queuing) on the approach.

6.1.2 HCM Implementation Challenges

The methodology to implement the aggregate models in the HCM can be expressed in three steps:

1. Define an upper bound on the operational models so that they do not assign an ATL flow that would violate the lane volume distribution in the HCM, namely the equal flow ratio condition.
2. Demonstrate how ATL operations can be predicted under actuated signal control in the context of HCM 2010 illustrative exercises.
3. Show how the upstream ATL length can be derived from the resulting analysis.

These steps are described in the following three sections.

6.1.3 Equal Flow Ratio Condition

The aggregate models in Equations 6-1 and 6-2 are straightforward and may be easily implemented into the HCM. Under certain conditions, however, either model may estimate an ATL flow rate which is greater than the current HCM prediction under the default lane volume distribution criteria in Chapter 18 of the HCM 2010 (*3*). In other words, the models should be capped at the ATL flow rate corresponding to a flow ratio equal to that of each CTL on the same approach. Therefore, if an *exclusive ATL* is contemplated, the upper bound for ATL flow for the single CTL case can be estimated using Equation 6-4:

$$\mathrm{V}_{\mathrm{ATL,\ MAX}} = V_T\left(1-\frac{0.50}{f_{LU}}\right) \tag{6-4}$$

In the case of two CTLs, the upper bound is computed per Equation 6-5:

$$\mathrm{V}_{\mathrm{ATL,\ MAX}} = V_T\left(1-\frac{0.667}{f_{LU}}\right) \tag{6-5}$$

Where:

V_T = total through flow, vph;
$V_{ATL,MAX}$ = upper bound for ATL flow, vph; and
f_{LU} = HCM 2010 lane utilization factor (Table 2-1).

In the case of a shared ATL, the lane utilization factor is no longer in play. Instead, the upper bound for ATL flow rate can be estimated on the basis of equalizing the flow ratio between the exclusive CTL and the shared ATL per Equation 6-6:

$$V_{ATL,MAX} = Max\left\{0, \frac{V_T}{N} \times \left[1-\frac{\frac{V_R}{S_R}}{\frac{V_T}{(N-1)S_T}}\right]\right\} \tag{6-6}$$

where:

N= number of CTL's and shared ATL on the approach,
V_R = right turn flow from the shared ATL (vph),
S_R = right turn saturation flow rate in vehicles per hour, and
S_T = through-movement saturation flow rate in vehicles per hour.

This technique reflects the tendency of drivers to generally seek the lane that will minimize their own service time, deploying in a manner that equalizes all lane v/s ratios serving through traffic. Note that under heavy right turn flow, the previous equation may not assign any through-movement flow to the shared lane, making it function as an exclusive or de facto right turn lane.

6.1.4 ATL Utilization under Actuated Control

One major challenge involved in the practical application of the ATL operational models is to account for the variation in signal timing associated with actuated signal control—the author's methods to account for this are discussed in this section but are described in more detail in an award-winning paper (*36*). An ATL removes traffic from the CTL(s), but this removal will inevitably shorten the green time for the approach. A decrease in green time in turn increases the degree of saturation for the through movement, and, based on Equations 6-1 and 6-2, the ATL flow. This then reduces the required green time. This cycle necessitates an iterative process that will eventually yield the appropriate ATL flow at equilibrium, as described in the flow chart in Figure 6-1.

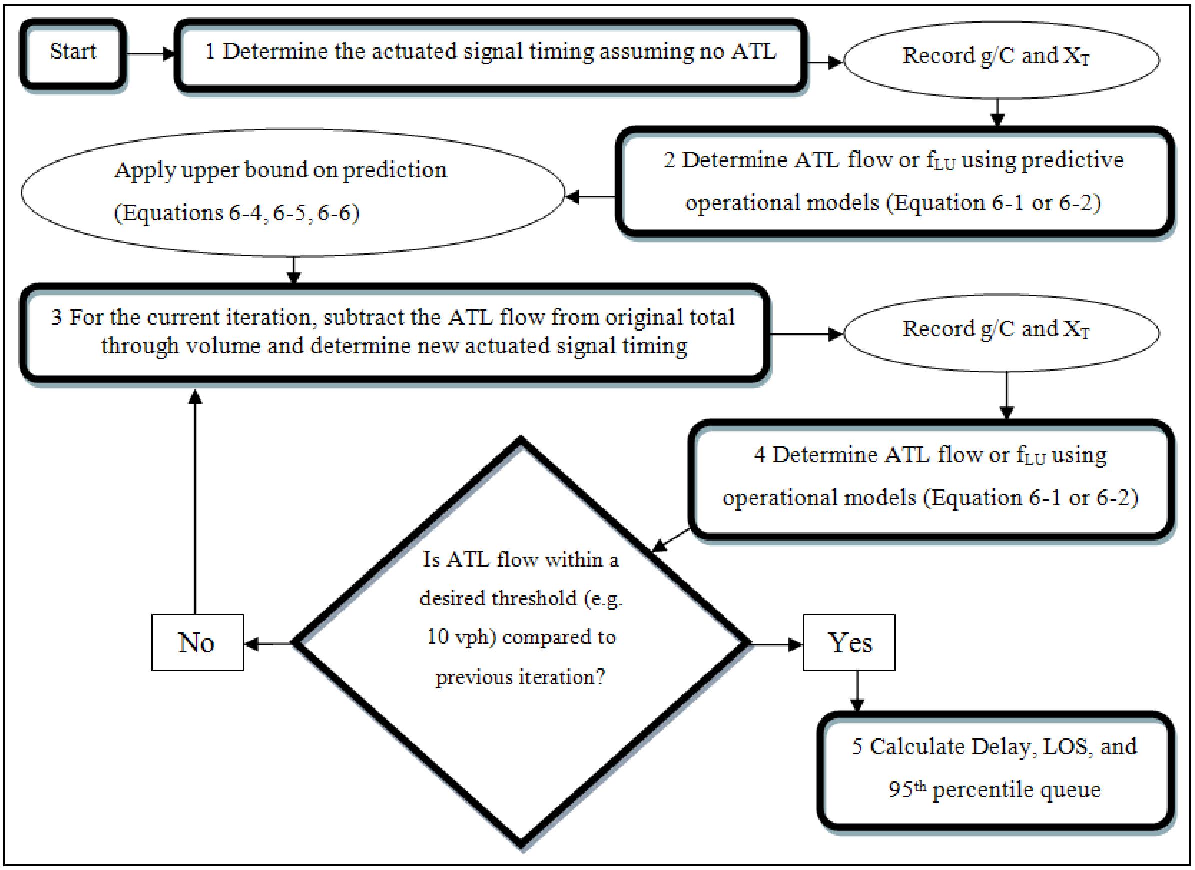


FIGURE 6-1. ATL Flow Estimation and Analytical Process

As the flow chart indicates, the analyst begins by using the HCM equations or software to determine the equilibrium actuated signal timing *as if the ATL did not exist.* This first step will yield the signal timing for the approach in question, including the effective green to cycle length ratio (g/C), which can then be used to calculate X_T. With these parameters (and X_R, if necessary), the analyst can then use Equation 6-1 or 6-2 to predict the flow that would occur in the ATL if it were added, taking into consideration the equal flow ratio condition described in Equations 6-4, 6-5, and 6-6. The third step accounts for the effect on actuated control of the shift in traffic to the ATL by subtracting the predicted ATL flow from the total through-movement flow, and the signal timing estimation is repeated. Using the new g/C and X_T, the analyst can then predict a new ATL flow and compare it to the previous result. The process repeats until the results converge within a desired threshold. For the purposes of this research, a threshold of 10 ATL vph was applied, although any arbitrarily low value could be used. At this point the analyst can calculate the desired performance measures. The example problems at the conclusion of this section demonstrate the technique to evaluate ATL operations under actuated control.

Alternatively, f_{LU} can be used in the procedure instead of ATL flow for an exclusive ATL. This may be useful to the practitioner who wishes to specify f_{LU} in an analysis package such as HCS+ or Synchro. Although either method can be used, for purposes of conversion, the f_{LU} can be calculated for a lane group as follows:

$$f_{LU} = \frac{Average\ lane\ volume}{Heaviest\ volume\ in\ any\ lane} = \frac{N \times V_T}{(N+1) \times [V_T - V_{ATL}]} \quad (6\text{-}7)$$

Where N = number of CTLs,

V_T = total through-movement flow (vph), and

V_{ATL} = ATL flow (vph).

In this case, the analyst would repeat the process in Figure 6-1 until f_{LU} or g/C converges to a desired level (within 0.01 g/C is likely sufficient).

6.1.5 Upstream Length Estimation

A key design task concerning ATLs is to determine the appropriate length of the ATL upstream component. Although it may be hypothesized that a longer ATL promotes higher ATL use, extensive field observations of ATLs did not support this idea (*6*, *7*). Instead, the primary motivator for using the ATL appears to be a defensive one: avoiding a cycle failure when traffic in the adjoining CTL is moderately to highly congested. Based on this premise, the required ATL upstream length is predicated on the provision of adequate storage for and access to the ATL from the neighboring CTL. Therefore the author recommends that the upstream ATL length be long enough to accommodate the predicted 95th percentile queue in the ATL *or* the adjacent CTL, whichever is greater. The calculation of the required upstream length, along with consideration of the challenges listed earlier in this section, is demonstrated in the following two illustrative exercises.

6.1.6 Example Problem 1

The first example in this section is based on Example Problem 1 in Chapter 18 of the HCM 2010 (*3*). Specifically, this example examines the effects of an ATL on lane grouping, fully actuated signal timing, and ultimately capacity and level of service for an approach with two CTLs. Two alternatives were developed for this example problem to investigate how to incorporate the ATL operational models into a signalized intersection analysis.

- Alternative 1: Add a shared ATL to the eastbound approach.
- Alternative 2: Add an exclusive ATL (and a right-turn pocket) to the eastbound approach.

Both alternatives are visually displayed in Figure 6-2 (the arrow indicates north) along with the baseline. In either case it is assumed that the upstream ATL length is long enough to continuously provide access to the ATL. The following section summarizes how the analytical approach and results vary under the proposed alternatives, including a comparison of the delay, level of service, and 95th percentile queue for each alternative.

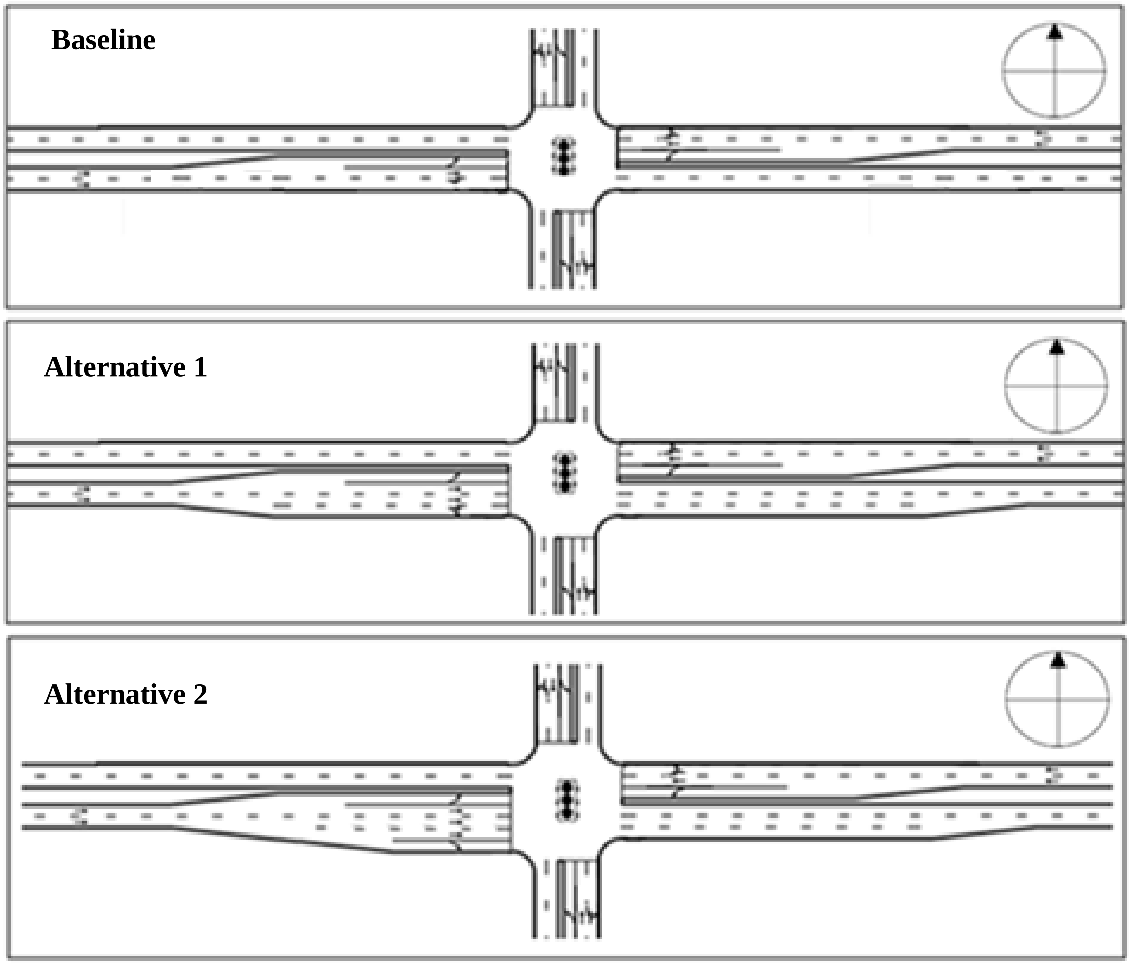


FIGURE 6-2. Diagram of Alternatives (Example 1)

The process begins by determining the actuated signal timing at equilibrium with no ATL present. The first iteration yields a g/C of 0.29, and an X_R equal to 0.46. Applying the through-movement flow and X_R in Equation 6-2 yields an ATL flow of 43 vph. However, due to the relatively high right turn demand when compared to the per-lane through-movement flow, the equal flow ratio condition in Equation 6-6 limits the ATL flow to 39 vph (and continues to govern the ATL flow for the rest of the procedure, as indicated by the shaded row). These 39 vph are then subtracted from the through-movement flow and the procedure continues until the results converge to 30 vph in the ATL. Table 6-1 displays a summary of the process used to determine the ATL flow for the eastbound approach (Iteration 1 encompasses steps 1 through 3 from Figure 6-1). The table indicates that the high level of right turns from the shared ATL will limit its use to 30 vph, or approximately nine percent of total through-movement flow. This value is nearly equal to the intercept term in Equation 6-2, indicating that the level of flow on the approach does not stimulate much ATL use.

TABLE 6-1. Summary of Alternative Analyses (Example 1)

Alternative	1			2		
Iteration	1	2	3	1	2	3
Through-movement Flow (vph)	318	279	292	318	234	248
Effective green time (s)	27.3	27.3	27.3	27.4	27.2	27.3
Equilibrium cycle length (s)	94	94	94	95	94	94
g/C	0.29	0.29	0.29	0.29	0.29	0.29
Saturation Flow Rate (pc/h)	3105	3105	3105	3105	3105	3105
X_T	0.35	0.35	0.35	0.35	0.35	0.35
X_R (Equation 6-3)	0.46	0.46	0.46	0	0	0
ATL Flow (Equation 6-2), vph	43	36	38	**84**	**70**	**72**
Upper Bound (Equation 6-6), vph	**39**	**26**	**30**	96	71	75
ATL Utilization, %	12.2	8.2	9.4	26.4	22	23.6
f_{LU}	0.76	0.73	0.74	0.91	0.85	0.87

Although the process is the same for the evaluation of Alternative 2, some of the controlling factors in Alternative 1 no longer dominate. The equal flow ratio condition does not control the procedure for Alternative 2 (note that the ATL flow is now shaded), and since the alternative has an exclusive ATL, X_R is set to zero. Consequently, this alternative generates greater ATL use, more than doubling the flow predicted in Alternative 1. Table 6-1 displays a summary of the process used to determine the ATL flow for the eastbound approach.

The final task in this exercise is to investigate the benefits of constructing an ATL in Alternatives 1 and 2 by comparing the delay, level of service, and 95th percentile queue for the alternatives with those in the baseline scenario. Table 6-2 displays the results of this comparison. In this example the ATL provides limited benefit: there is no improvement in delay, but the 95th percentile queue is reduced from 160 feet to 100 feet. Additionally, there is no discernible operational benefit from adding an exclusive right turn lane. The limited benefit of the ATL in this example is due to the low eastbound through-movement demand, which provides little incentive for drivers to use the ATL.

TABLE 6-2. Summary of Performance Measures for Eastbound Approach (Example 1)

Geometry	Baseline	Alternative 1	Alternative 2
Approach Through-movement Delay (sec/veh)	28	27	26
Level of Service	C	C	C
95th Percentile Queue (ft)	160	100	100
Intersection Delay (sec/veh)	25	25	25
Intersection Level of Service	C	C	C

6.1.7 Example Problem 2

This exercise is a modified version of the previous HCM 2010 example problem with the following adjustments:

- The northbound approach is examined for the addition of an ATL.
- All through-movement flows are halved.

- The lane geometry for the baseline and alternatives are reduced to those displayed in Figure 6-3.
- All other flows (left turns, right turns, and pedestrians) are unchanged.

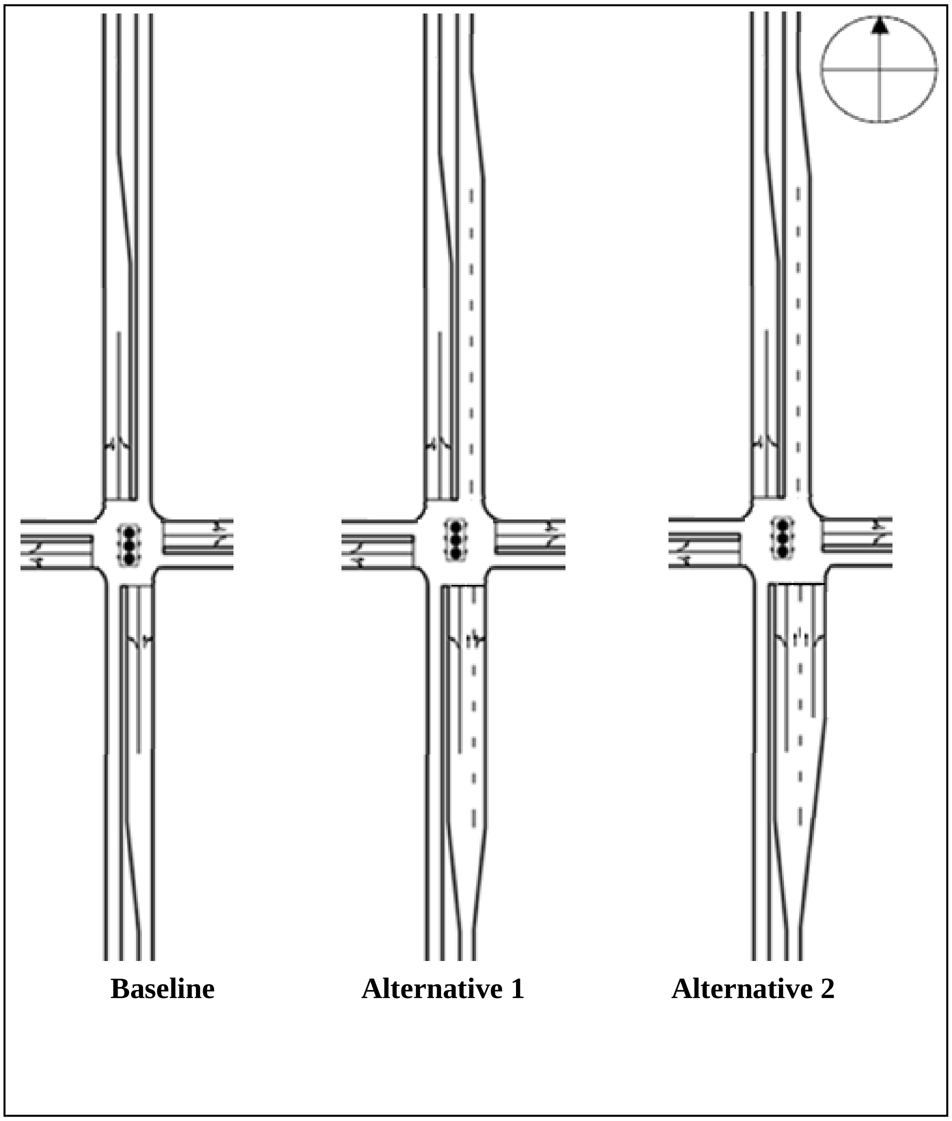


FIGURE 6-3. Adjusted Lane Geometry for Example Problem 2

This example problem is used to demonstrate how the procedure would work for a congested approach with an ATL and only one CTL. The alternatives in this exercise are similar to those in the first example problem but apply to the northbound approach as follows:

- Alternative 1: Add a shared ATL to the northbound approach.
- Alternative 2: Add an exclusive ATL (and a right-turn pocket) to the northbound approach.

Again it is assumed that the upstream ATL length is long enough to continuously provide access to the ATL. The following section summarizes how the analytical approach and results would change under the new alternatives using a comparison similar to that in the first example problem.

The process begins by determining the actuated signal timing at equilibrium assuming there is no ATL. This first iteration yields a g/C of 0.52 and an X_T of 0.85. The through-movement flow and X_T can then be used in Equation 6-1, yielding an ATL flow of 191 vph, which is below the upper bound calculated from Equation 6-6. These 191 vph are then subtracted from the through-movement flow and the procedure continues until convergence to 145 vph in the ATL. Table 6-3 displays a summary of the process used to determine the ATL flow for the northbound approach (Iteration 1 encompasses steps 1 through 3 of Figure 3). This particular example indicates that the predicted ATL flow can fluctuate up or down with each iteration before finally converging.

TABLE 6-3. Summary of Alternative Analyses (Example 2)

Alternative	1				2			
Iteration	1	2	3	4	1	2	3	4
Through-movement Flow (vph)	822	631	688	673	822	620	678	663
Effective green time (s)	48.73	29.92	34.6	33.3	37.15	22.54	25.81	24.86
Equilibrium cycle length (s)	94	68	74	72	78	58	62	61
g/C	0.52	0.44	0.47	0.46	0.48	0.39	0.42	0.41
Saturation Flow Rate (pc/h/l)	1863	1864	1865	1866	1863	1864	1865	1866
X_T	0.85	0.77	0.79	0.78	0.93	0.86	0.87	0.87
X_R (Equation 6-3)	0.11	0.13	0.12	0.12	0	0	0	0
ATL Flow (Equation 6-1), vph	**191**	**134**	**149**	**145**	**202**	**144**	**159**	**155**
Upper Bound (Equation 6-6), vph	359	263	292	284	390	295	322	315
ATL Utilization, %	23.2	16.3	18.1	17.6	24.6	17.5	19.3	18.9
f_{LU}	0.65	0.6	0.61	0.61	0.66	0.61	0.62	0.62

A similar process was used to calculate the ATL flow in Alternative 2, which yielded higher ATL flow than Alternative 1 due to the presence of an exclusive right turn lane, as indicated in Table 6-3. The final task in this exercise is to investigate the benefits of constructing the ATLs in Alternatives 1 and 2 by comparing the delay, level of service, and 95th percentile queue for the alternatives with those in the baseline scenario. Table 6-4 displays the results of this comparison. In this situation the ATL would result in drastically decreased delay for the northbound through movement, although there would not be much benefit from adding a right turn lane.

TABLE 6-4. Summary of Performance Measures for the Northbound Approach (Example 2)

Geometry	Baseline	Alternative 1	Alternative 2
Approach Through-movement Delay (spv)	43	16	17
Level of Service	D	B	B
95th Percentile Queue (ft)	700	300	300
Intersection Delay (spv)	32	21	17
Intersection Level of Service	C	C	B

6.1.8 Summary of HCM Implementation

These two example problems demonstrate how the challenges of accounting for ATLs in the HCM signalized intersection procedure can be addressed in a realistic scenario. They also indicate that low levels of congestion can lead to low ATL use—specifically, the intersection benefits more in the second problem than in the first problem because an ATL is considered for a more congested approach. Thus, the comparison of these example problems provides some guidance for when an ATL may be more appropriate. In both problems, the maximum number of iterations required to evaluate any ATL alternative is four, implying that the new process is simple and brief.

The methods described in this section indicate that with some modifications to HCM methodology, the ATL operational models can be adequately applied as part of signalized intersection analysis. Specifically, the effect of actuated signal control on ATL operations, while seemingly a challenging procedure, is actually a straightforward process that requires only a few iterations. With the effort presented here, the author hopes that practitioners may have a better understanding of ATL mechanics and be better-equipped to gauge the effects of an ATL on intersection capacity.

Upon review of the results of this study, the author recommends that the following items be incorporated in the HCM procedure for analysis of signalized intersection capacity:

- A more detailed and appropriate explanation of the effect of an ATL on the lane utilization adjustment factor f_{LU}.
- Incorporation of the procedure to evaluate ATL operations under actuated signal timing in both the HCM Chapter 18 text and the computational engine.
- Explanation of ATL operations in a separate example problem similar to the exercises already contained in the HCM 2010.

Inclusion of these three items within the HCM will ultimately provide practitioners with a straightforward method to evaluate the capacity of a signalized intersection where an ATL is present.

6.2 Microsimulation Implementation

This section contains a discussion of the current treatment of ATLs in microsimulation systems and the author's recommendation for incorporation of the disaggregate models described in Chapter 4 into these systems. Without calibration, microsimulation tools assign some vehicles to the ATL as a function of basic lane-changing algorithms, which may result in an ATL utilization different than observed in the field. The first part of this section highlights the conclusions taken from the author's published paper which concerns calibrating a microsimulation network to achieve the same results as the aggregate models (*38*). The remainder of this section discusses a method to implement the disaggregate models and also investigates the author's simulation algorithm described in Section 5.3.1.

6.2.1 ATL Microsimulation Analysis Approach Development

To begin an investigation of how ATLs operate in microsimulation, the author first performed a review of the literature concerning microsimulation lane change algorithms and previous studies of ATLs in these systems (*4,* 9). As the introduction to this dissertation states, microsimulation systems model the acceleration of individual vehicles using car-following algorithms, which are ultimately controlled by mandatory and voluntary lane changes. Although mandatory lane changes control necessary movements such as right turns or the downstream merge of an ATL, voluntary lane changes consist of movements that do not result in a different destination, a key example of which is lane choice. In areas where voluntary lane changes are permitted (e.g. upstream of a signalized intersection), the car-following algorithm takes effect. ATL use in microsimulation is primarily controlled by these car-following algorithms—particularly when vehicles move around long queues or slower-moving vehicles—but the simulated ATL use is often unrealistically high without specifically calibrating the lane change rules. Figure 6-4 displays an example of the need for this calibration. In the left-hand screenshot of a simulated network of northbound Garrett at Chapel Hill Road (approach 13 in Table 1-1), the ATL utilization appears to be nearly 50 percent, as the simulated vehicles do not treat the ATL differently than the CTL. The right-hand screenshot displays the calibrated network, where the ATL utilization is closer to the average field-observed utilization of 19 percent.

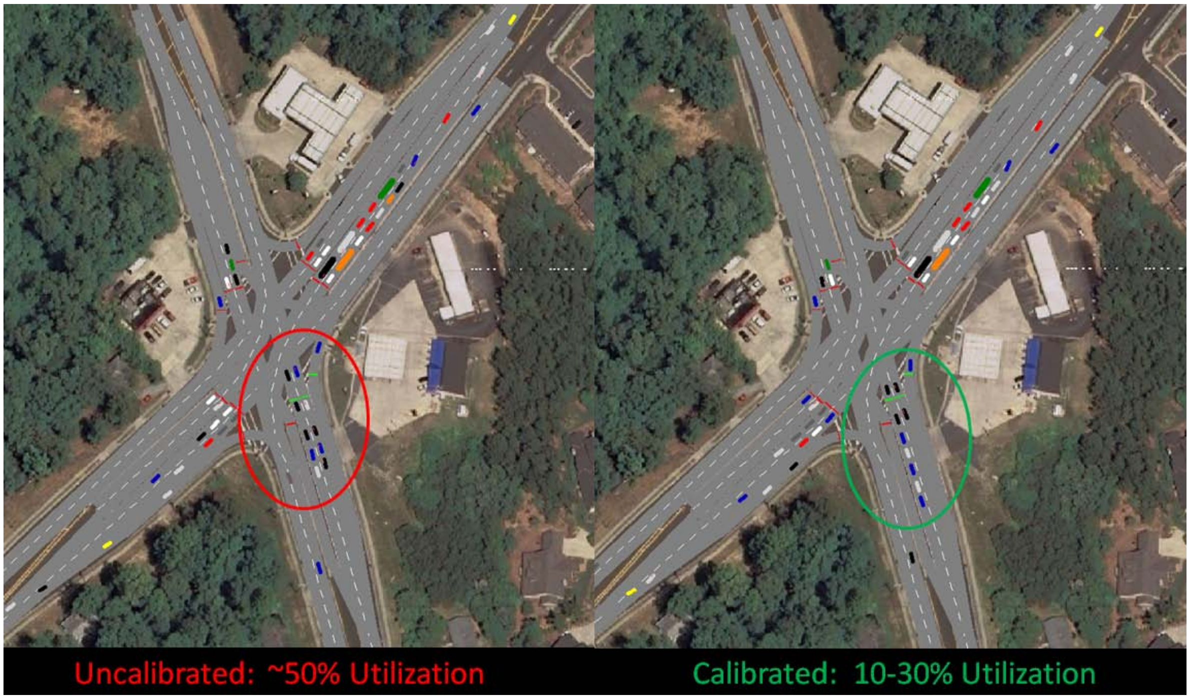


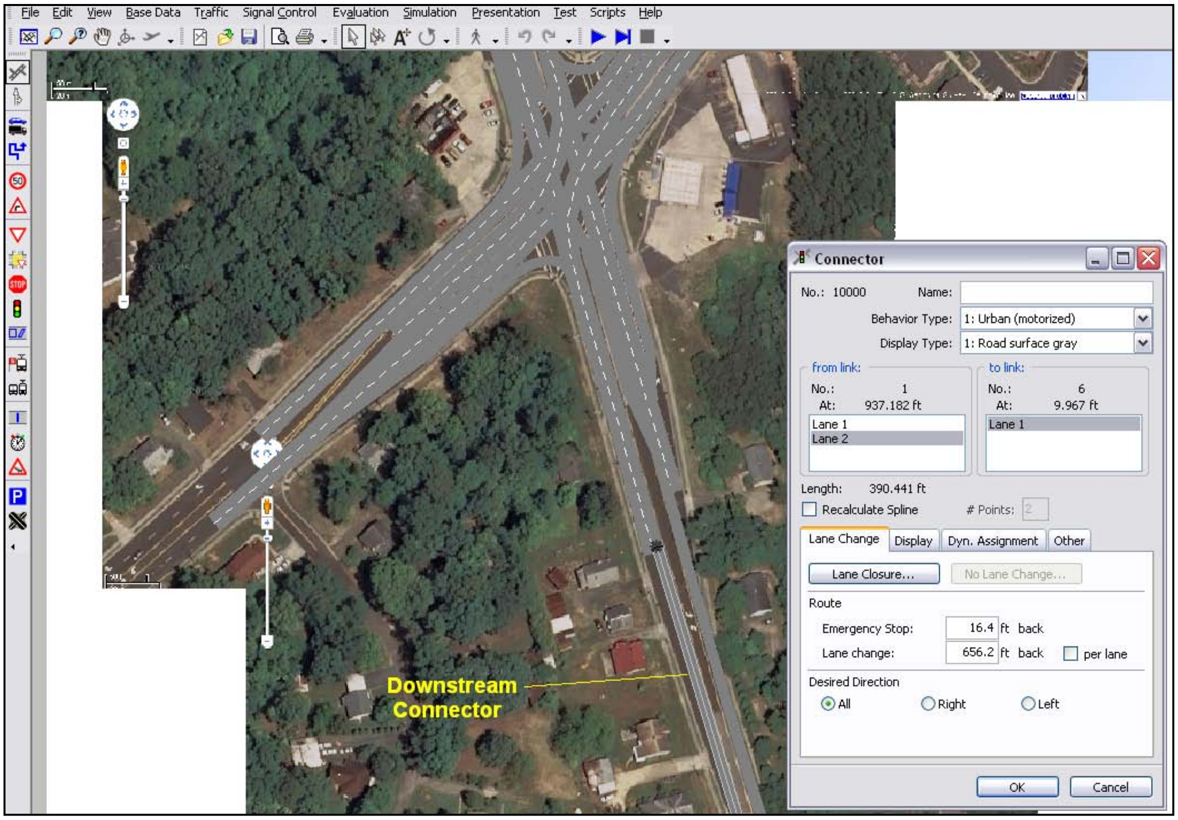
FIGURE 6-4. Screenshot of Uncalibrated and Calibrated Microsimulation of ATLs (*38*)

One parameter that controls these lane change algorithms is the upstream decision distance (UDD), a characteristic of the downstream connector or portion of the ATL. This UDD is typically measured relative to the ATL lane drop and refers to the point at which simulated drivers begin to be concerned with the lane drop. The UDD describes the point at which the mandatory lane change algorithm becomes active. In most simulation tools, drivers will begin to try and merge at this decision point if gaps are available, and they will become increasingly aggressive about their lane-changing behavior as the distance to the downstream drop decreases. Furthermore, in most cases, the mandatory lane change algorithm will override any voluntary lane changes. As a result, no voluntary lane changes will take place past the upstream ATL decision point (within the UDD), and consequently no CTL-to-ATL maneuvers will take place past that point. In this context it is important to emphasize that a coded UDD that is greater than the total ATL length *will prevent any voluntary lane changes into the ATL and will therefore result in zero through flow on the ATL.*

The procedure to develop an ATL analysis approach in simulation can best be summarized in the following steps:

1. Select microsimulation package
2. Select field data for calibration
3. Calibrate simulation to achieve the correct driver behavior, travel times, and lane utilization
4. Develop a UDD prediction model based on the results of the lane utilization calibration

The author used VISSIM as the microsimulation package of choice, as it was also used for a related study and data were readily available (*1*, *39*). In VISSIM, the UDD is called the lane change distance (LCD) for the lane connector downstream of the ATL—a screenshot is displayed in Figure 6-5.



No.: 10000

Name:

Behavior Type: 1: Urban (motorized)

Display Type: 1: Road surface gray

from link:

No.: 1

At: 937.182 ft

Lane 1

Lane 2

to link:

No.: 6

At: 9.967 ft

Lane 1

Length: 390.441 ft

☐ Recalculate Spline

Points: 2

Route

Emergency Stop: 16.4 ft back

Lane change: 656.2 ft back ☐ per lane

Desired Direction

● All ○ Right ○ Left

FIGURE 6-5. Screenshot of VISSIM Lane Change Distance (LCD) (*38*)

Although VISSIM was used in this study, it is expected that other microsimulation packages can be calibrated by modifying the UDD, and other UDD prediction models can be developed using the same techniques described in the following section. However, since the reminder of this section is based on the algorithms in VISSIM, its terminology of LCD will be adopted henceforth to describe the more general UDD.

Table 6-5 displays a summary of the sites used to calibrate a model to predict the lane change distance as a function of ATL elements, including upstream and downstream ATL length, demand, and other operational characteristics input in VISSIM. Consistent with any simulation analysis, the parameter set used in the simulation model should be calibrated to match field conditions or known relationships in traffic flow theory. Calibration can include various changes to built-in simulation algorithms, including speed distributions, car-following logic, or lane-changing parameters. The following three parameters were calibrated in VISSIM to match field observations:

1. Driver acceleration in each lane
2. Travel time in each lane through the entire ATL approach
3. ATL utilization

The ATL utilization was calibrated for every site in Table 6-5 to develop the LCD prediction model.

TABLE 6-5. Summary of Sites Used in VISSIM Calibration

#	Approach	Location	# of CTLs	ATL Type	Avg. ATL Utilization (%)	Calibration Studies 1, 2, or 3
1	EB Walker Rd at Murray Blvd	Beaverton, OR	1	Shared	28	3
2	WB Walker Rd at Murray Blvd	Beaverton, OR	1	Shared	29	3
3	EB NC-54 at Fayetteville Rd	Durham, NC	1	Exclusive	23	1,2,3
4	NB La Canada Dr at Magee Rd	Tucson, AZ	1	Shared	19	3
5	SB La Canada Dr at Magee Rd	Tucson, AZ	1	Shared	18	3
6	EB Magee Rd at La Canada Dr	Tucson, AZ	1	Shared	19	3
7	WB Magee Rd at La Canada Dr	Tucson, AZ	1	Shared	14	3
8	NB La Canada Dr at Orange Grove Rd	Tucson, AZ	1	Shared	19	3
9	SB La Canada Dr at Orange Grove Rd	Tucson, AZ	1	Shared	19	3
10	EB Walker Rd at 185th St	Beaverton, OR	1	Exclusive	40	3
11	WB Walker Rd at 185th St	Beaverton, OR	1	Shared	15	3
12	SB Sunset Lake Dr at Holly Springs Rd	Holly Springs, NC	1	Shared	9	1,3
13	NB Garrett Rd at Old Chapel Hill Rd	Durham, NC	1	Exclusive	19	1,3
14	SB Garrett Rd at Old Chapel Hill Rd	Durham, NC	1	Exclusive	23	1,3
15	NB MD-2 at Arnold Rd	Annapolis, MD	2	Exclusive	19	1,2,3
16	SB MD-2 at Arnold Rd	Annapolis, MD	2	Exclusive	20	1,2,3
17	EB MD-214 at Kettering Dr	Bowie, MD	2	Exclusive	5	3
18	NB IL-171 at IL-64	Melrose Park, IL	2	Shared	18	3
19	SB IL-171 at IL-64	Melrose Park, IL	2	Shared	18	3
20	NB-IL 171 at Roosevelt Dr	Melrose Park, IL	2	Shared	6	3
21	SB-IL 171 at Roosevelt Dr	Melrose Park, IL	2	Exclusive	26	3
22	SB US-1 at New Falls of Neuse Rd	Wake Forest, NC	2	Exclusive	13	3

6.2.2 Acceleration Rates

Average acceleration rates are an indicator of driver aggressiveness and were shown to affect ATL utilization in VISSIM (*9*). The author hypothesized that ATL users would be intrinsically more aggressive and accelerate faster from the stop bar. The chief benefit of VISSIM's microscopic simulation is the ability to calibrate driver behavior, particularly the aggressive behavior hypothetically associated with ATL use. The acceleration rate from a stopped position of the leading vehicle in each lane was recorded in the field by assuming a constant acceleration rate and then measuring the time for each vehicle to travel a fixed distance. The following kinematic equation allows for this calculation:

$$a = \frac{2\Delta x}{(\Delta t)^2} \tag{6-8}$$

Where

a = average acceleration rate (ft/s^2),

Δx = distance (ft), and

Δt = time (s).

For each approach, the distance used for the calculation was 100 feet. Acceleration data were only recorded if there were stopped vehicles in both the ATL and the CTL(s) at the end of the red phase, as it would be useless for a driver in the ATL to accelerate quickly if there were no downstream merging conflict with a CTL user, and vice versa. Figure 6-6 shows a plot of the cumulative distribution of vehicle acceleration by lane.

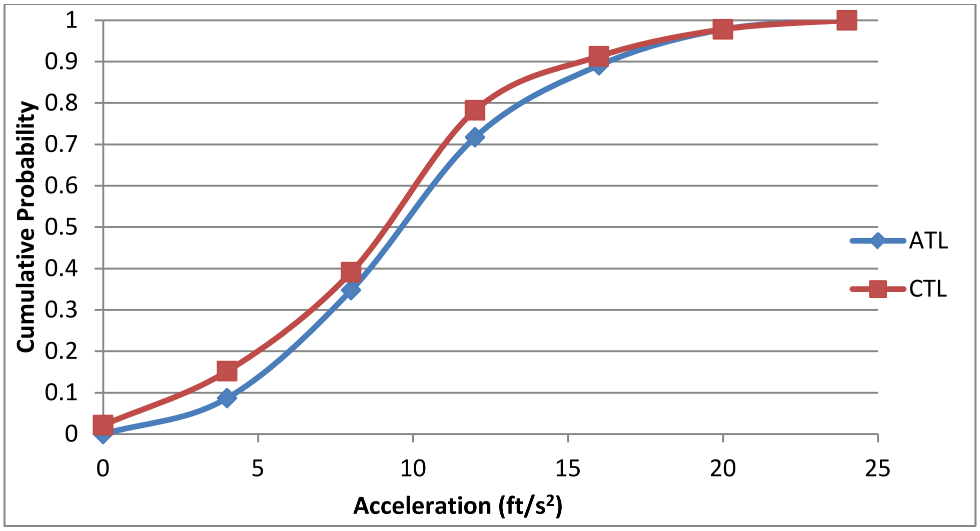


FIGURE 6-6. Cumulative Distribution of Acceleration Rate by Lane

Although the ATL acceleration rate was higher than the CTL acceleration rate for nearly all percentile levels, a K-S test concluded that at a 5% level of significance ($\alpha = 0.05$), there is no significant difference between the acceleration distributions of the ATL and CTL vehicles. The sample size of the study was 46 vehicles per lane across six ATL approaches.

6.2.3 Travel Times

The travel time through each lane was calculated using synchronized video recordings of the upstream and downstream segments of the approach. Travel time segments were chosen so that the entry point was placed far enough away from the intersection to capture any deceleration due to queuing. Full sampling of each lane was used at Approach 3, but full sampling was deemed impractical at Approaches 15 and 16 due to the high volume of traffic there. At this site, six data points were recorded during each cycle: one travel time in each lane arriving on green (free flow) or red, joining the queue. In either case, an effort was made to match the selected vehicles by the time that they arrived at the intersection.

Each travel time observation was used to compute the travel time delay in each lane, defined as the difference between the observed travel time and the "free flow" travel time at the posted speed limit. Two techniques were used to compare the travel time delay in the CTL(s) with the travel time delay in the ATL. The first was to normalize the delay to a length of 1000 ft, as shown in the equation

$$\text{Delay / 1000 ft} = \frac{Observed\ Travel\ Time - Free\ Flow\ Travel\ Time}{Travel\ Time\ Segment\ Length\ (ft)} \times 1000 \tag{6-9}$$

The second method of comparing the delay in each lane was to compute the Delay %:

$$Delay\ \% = \frac{Observed\ Travel\ Time - Free\ Flow\ Travel\ Time}{Free\ Flow\ Travel\ Time} \times 100\% \tag{6-10}$$

Each study site was coded in VISSIM using available signal timing and turning movement counts for the appropriate peak hour. The researchers also coded travel time segments in VISSIM in order to closely replicate the segments recorded in the field. These field-observed travel times were used to validate the VISSIM model. Table 6-6 displays a summary of this comparison, including the average field and simulated travel times and the standard deviation and sample size for the field data. Travel times are aggregated over both lanes, and vehicles arriving during effective green and effective red were recorded separately.

TABLE 6-6. Summary of Travel Time Comparison

Site	Overall Travel Time (seconds)			
	Arriving on Green		Arriving on Red	
	Field	Simulation	Field	Simulation
EB NC-54 at Fayetteville Rd	*14.5	*14.7	64.8	77.4
NB MD-2 at Arnold Rd	*14.9	*14.1	68.1	52.7
SB MD-2 at Arnold Rd	14.6	12.6	71.4	52.6

Site	Overall Travel Time (seconds)			
	Arriving on Green		Arriving on Red	
	Field Sample Size	Field St.D.	Field Sample Size	Field St.D.
EB NC-54 at Fayetteville Rd	54	2.2	88	19.2
NB MD-2 at Arnold Rd	30	2.6	30	15.9
SB MD-2 at Arnold Rd	60	4.2	60	23.8

*At α=0.05, a two-tailed t-test concluded that there was insufficient evidence to reject H_0

The table indicates that the simulated travel times for vehicles arriving during the green phase matched very closely with the field-observed travel times—in fact, a t-test failed to reject the null hypothesis that the field and simulated travel times are equal at two approaches. The travel time variance was much higher for vehicles arriving during effective red, but the t-test still showed a significant difference between the field and simulated travel times in this case. However, the arriving-on-red travel times were highly variable and were likely dependent upon each vehicles actual arrival time. Additionally, while the field and simulated travel times were statistically distinguishable, the magnitude of the simulated travel times was reasonable given that the cycle lengths at these sites were all above 100 seconds.

6.2.4 ATL Utilization

The primary goal in the calibration of a simulated ATL approach is to match the field-observed ATL utilization or the ATL flow predicted by operational models. Lane-by-lane counts were extracted from video recorded in the field in order to calculate the average ATL utilization at each site. Only data collected during the peak hour was used, and the utilization remained surprisingly consistent within each site over varying levels of through-movement flow.

The LCD of the downstream connector at each ATL site was modified using trial-and-error in order to achieve the field-observed average ATL utilization. This proved to be an accurate method to calibrate VISSIM, as shown in Figure 6-5.

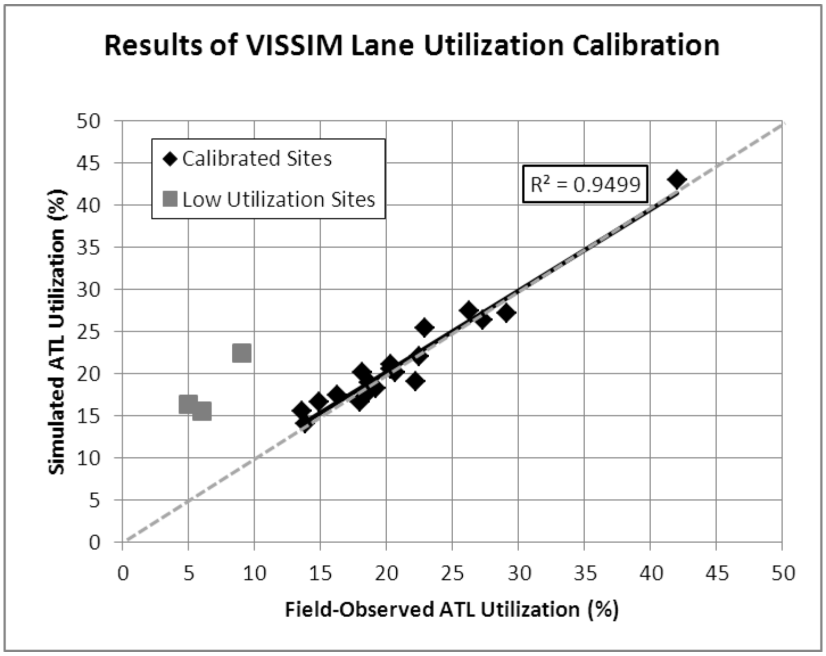


FIGURE 6-7. Simulated versus Field ATL Utilization

As Figure 6-7 indicates, each of the sites with average ATL utilization greater than ten percent could be accurately modeled in VISSIM by calibrating the LCD. Unfortunately, the three sites that experienced the lowest ATL utilization could not be accurately modeled using this method—it appeared that VISSIM assigned some vehicles to the ATL no matter how low the total through-movement flow. From observations at these three approaches, it appears that the low utilization is due to extremely low congestion levels and general reluctance of drivers to use the ATLs without immediate benefit. The gray dashed lane in Figure 6-7 refers to the perfect fit relationship, while the black line shows the results of a linear regression fit between simulated and field-observed utilization after utilization. The associated R-Square of 0.9499 indicates a very successful calibration effort in terms of replicating field-observed utilization in the simulation.

6.2.5 LCD Prediction Model Development

Although the effort to calibrate the lane utilization using the LCD proved to be accurate, it is also necessary to develop a method to simulate a planned ATL before construction. In this case, there may be no knowledge of the eventual ATL utilization, and a practitioner may wish to simulate the planned ATL instead of using the operational models mentioned earlier in the paper. The following section presents the method used to develop such a model to predict the LCD when only basic knowledge of the ATL is known.

For model development, the LCD was quantified in one of three ways:

- LCD %: the percentage of the upstream segment of the ATL which is covered by the LCD, computed as $LCD\% = \frac{LCD\ -\ Downstream\ Length}{Upstream\ Length} \times 100\%$ (6-11)
- LCD FT: the exact LCD expressed in feet
- LCD % Total: the LCD expressed as a percentage of the total ATL length, computed as

$$LCD\%TOTAL = \frac{LCD}{Total\ ATL\ Length} \times 100\% \tag{6-12}$$

Each of these three variables was modeled using Statistical Analysis Software (SAS) as a function of several independent variables (*31*). Several variables were hypothesized to affect the LCD used to calibrate VISSIM. These variables are defined as follows:

- Volume: the volume of the through-movement expressed in vph
- Volume/Lane: the through volume divided by the number of CTL's
- Upstream: the length of the ATL segment upstream of the stop bar
- Up/Down: the ratio of the upstream segment of the ATL to the downstream segment
- Speed: the approach speed as modeled in VISSIM (in mph), usually the posted speed limit
- Speed/Total: the ratio of the approach speed (in fps) to the total ATL length (in feet)
- D_{CTL}: a binary variable to signify the number of CTL's: $D_{CTL} = 0$ for a 1-CTL approach, $D_{CTL} = 1$ for a 2-CTL approach

A few other variables, such as total length and downstream length, were modeled in SAS but with no significance. SAS stepwise regression using a forward selection method at a significance threshold of $p = 0.05$ was used to model each dependent variable as a function of the independent variables (*31*).

6.2.6 LCD Prediction Model Results

A total of nine models were developed using the SAS stepwise regression procedure. These models are displayed in Table 6-7.

TABLE 6-7. Summary of LCD Models

Model #	Dependent	R^2	Intercept	Volume/Lane	Upstream	Volume	Speed	D_{CTL}	Up/Down	Speed/Total
A	LCD %	0.432	174.79*			-0.01937*	-2.6973*			
B	LCD %	0.434	178.89*	-0.01118*		-0.01489*	-2.7259*			
C	LCD %	0.435	164*				-2.64*	-25.75*		
D	LCD FT	0.644	503.08*		0.4442**		-11.101*	-616.98**		
E	LCD FT	0.629	44.17*		0.413**			-659.58**		
F	LCD FT	0.671	340.01*					-456.6**	187.52*	-9019.57*
G	LCD % TOTAL	0.622	89.696***		-0.01125*	-0.0172*				

p-value: *<.05 **<.01 ***<.001

Several other models were developed but did not explain a significant enough amount of variability in the data to be presented here. The SAS stepwise regression recommended one combination of independent variables for each dependent variable:

Model (C): $LCD\% = 164 - 2.64(Speed) - 25.75(D\ CTL)$ R^2=0.435

Model (F): $LCD\ FT = 340.01 - 456.6(D\ CTL) + 187.52\left(\frac{Up}{Down}\right) - 9019.57\left(\frac{Speed}{Total}\right)$ R^2=0.671

Model (G): $LCD\%Total = 89.696 - .01125(Upstream) - .0172(Volume)$ R^2=0.622

From inspection of these three models, it appears that Model (F) is both the easiest to implement (as it computes LCD directly) has the best fit (R^2 = 0.671), and has the most statistically significant variables. However, its independent variables are more esoteric. The model assumes that the LCD begins at 340.01 feet, which is not unreasonable considering the range of ATL lengths, and that 456.6 feet are subtracted from the LCD if there are 2 CTL's. Then the LCD is increased if the ratio of the upstream length to the downstream length is high. This is not consistent with field observations, which suggest higher utilization when upstream length increases. Finally, the LCD is decreased if the relative speed of the approach is high, which is difficult to confirm with field observations.

Model (G) has nearly the same fit as Model (F), but its independent variables are much more intuitive. The model suggests that the LCD begins at 89.696% of the total ATL length, which is approximately the highest value observed in previous VISSIM calibration. Then the LCD%Total is reduced for increasing upstream length and through volume, which implies that ATL utilization increases with increasing upstream length and through volume. This is consistent with field observation. Consequently, this model was selected for further exploration. The next step in developing a model to express LCD%Total as a function of through volume and upstream length was to test the linearity of the variables. Figure 6-8 displays a plot of LCD%Total against upstream length.

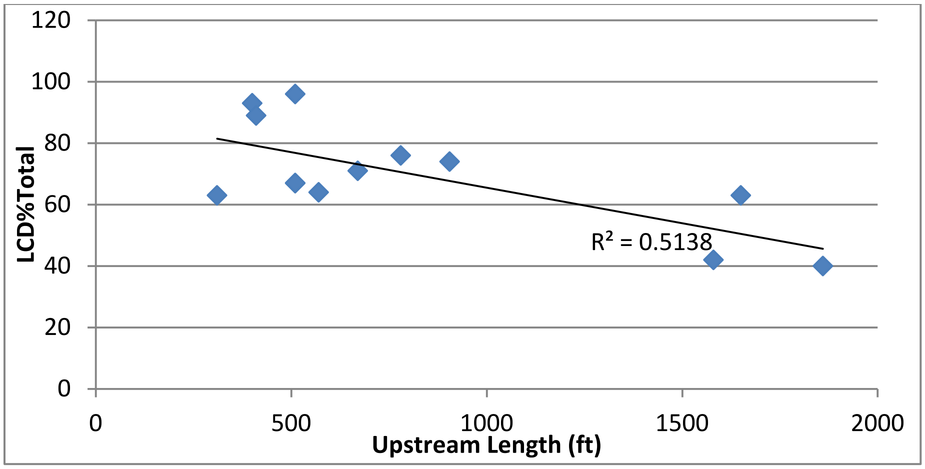


FIGURE 6-8. LCD%Total versus Upstream Length for Model (G)

A regression analysis with other powers of upstream length (e.g., length squared) revealed that the relationship between LCD%Total and upstream length is best approximated as linear.

To further explore Model (G), the author wished to judge how sensitive the ATL utilization was to changes in the LCD and total through-movement flow. Although it was hypothesized that the ATL utilization would decrease as the LCD approached the total length of the ATL, a sensitivity analysis was necessary to determine the importance and robustness of the LCD prediction model. This was pursued by coding an ATL approach with 1-CTL in VISSIM and then varying the LCD and entering through-movement volume along the approach. The ATL utilization and delay were then recorded from the VISSIM output. These results are displayed in Figure 6-9.

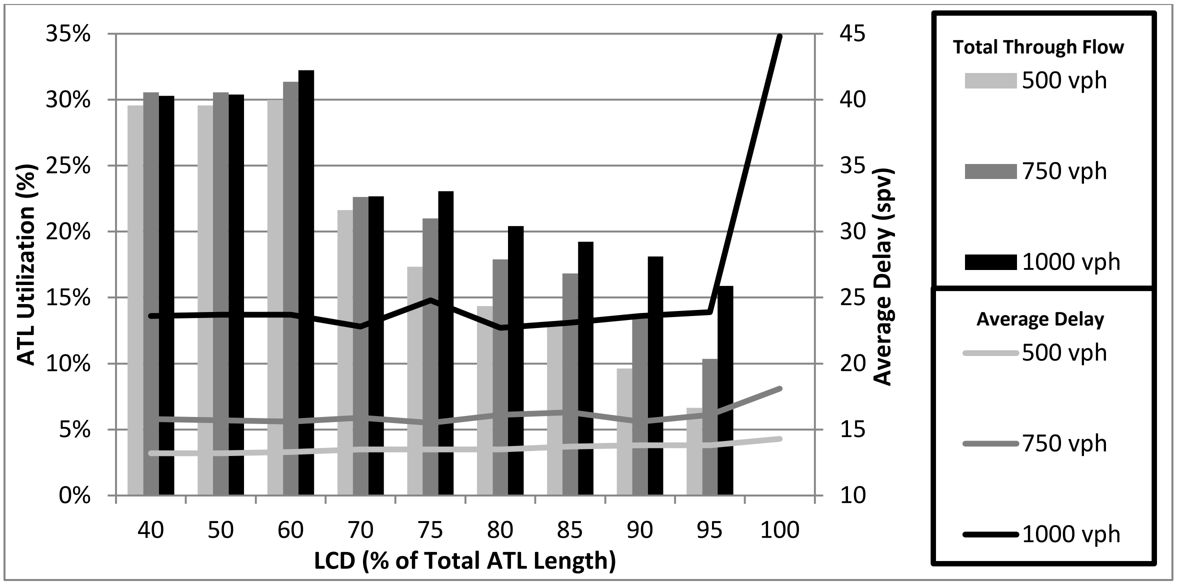


FIGURE 6-9. LCD Sensitivity Analysis Results

Figure 6-9 displays the ATL utilization on the left-hand vertical axis and the average delay for all through-movement vehicles on the right-hand vertical axis. Delay was defined as the difference between the free flow and signalized travel times over the entire travel time segment, and it is reported here instead of actual travel time in order to better compare the differences between scenarios. LCD values below 40% are not displayed because the ATL utilization did not appear to be affected by changes in LCD below 50% of the total ATL length.

As the figure indicates, the relationship was linearly decreasing between an LCD of 50% and 95%, but when the LCD was increased beyond 95% of the ATL length, the utilization quickly dropped to zero as simulated vehicles were aware of the lane drop as soon as they moved into the ATL, causing them to move back into the CTL before the intersection. The LCD predicted by model (G) for the 500, 750, and 1,000 vph scenarios were 70%, 70%, and 60%, respectively. At a green ratio of approximately 0.5 and an assumed saturation flow rate of 1,800 vehicles per hour in the CTL only, the equivalent v/c ratios for the three scenarios are roughly 0.54, 0.81, and 1.08 expressed relative to the capacity of the continuous lane only.

Interestingly, the overall delay was not strongly affected by varying the LCD (and consequently the ATL utilization) below 95%. This is likely because the approach experienced a relatively low v/c ratio (measured across both lanes) and was not very congested. The ATL utilization also appeared quite sensitive to volume, and the range of ATL utilization yielded by VISSIM decreased as volume increased.

6.2.7 Discussion of Microsimulation Analysis Procedure

The results presented in this section suggest that an ATL facility can be readily modeled in a microsimulation environment with a limited need for input data. In particular, if an analyst is studying the feasibility of an ATL intersection improvement in VISSIM, the following list of steps represents a proposed analysis work flow. Additional steps may be necessary, depending on the specific location, and the practitioner should exercise sound judgment in any simulation analysis.

1. Gather input data including existing and proposed intersection geometry, traffic turning movements (current and future forecast), approach speed limits, and signal timing data
2. Model baseline representing the existing intersection without ATL approaches.
3. Calibrate baseline by comparing the modeled operations to field data or other analysis approaches. Make any necessary adjustment to traffic volumes, speed inputs, signal timing, or other simulation algorithms.
4. Estimate initial LCD parameter using the predictive model in this paper as a function of the total (future) through traffic flow and proposed total ATL length. An initial estimate of the ATL upstream and downstream lengths is therefore needed for this analysis. Estimate ATL predicted volume, using the operational models described earlier. These estimates will be used to validate that the ATL utilization is modeled correctly.

5. Model ATL geometry using proposed geometry, signal timing, and volumes (step 1), and the initial LCD parameter from Step 4a.
6. Calibrate ATL operations by modifying the LCD until the simulated ATL volume matches (approximately) the predicted volume from Step 4b. As a general guidance, a longer LCD will result in lower utilization of the ATL.
7. Evaluate ATL performance by running repeated iterations of the baseline and ATL scenarios and comparing the average performance. A suggested performance measure is the total through travel time, which is readily compared to field data. Additionally, approach delay and queue lengths are important performance measures that are also predicted in the deterministic HCM analysis approach.

6.2.8 Evaluation of Simulation Algorithm for Disaggregate Models

This section contains an evaluation of the simulation tool described in Section 5.3.1. Although the author's primary focus was to develop an Excel-based tool to achieve an appropriate comparison between the aggregate and disaggregate models, the tool also provides a demonstration of how the disaggregate models can be used as a target lane algorithm in microsimulation. The algorithm was displayed in Figure 5-1, and a screenshot of the Excel spreadsheet was displayed in Figure 5-2. The author simulated 50 runs of each datapoint in order to make the comparison between the aggregate and disaggregate models in Chapter 5. What follows here is a sensitivity analysis of the algorithm that uses the same dataset (Table 5-1) and indicates how a change in the input data will affect the simulated ATL flow. First the author investigated the relationship between ATL flow and total through-movement flow to check whether the algorithm could simulate the relationship—this is plotted in Figure 6-10.

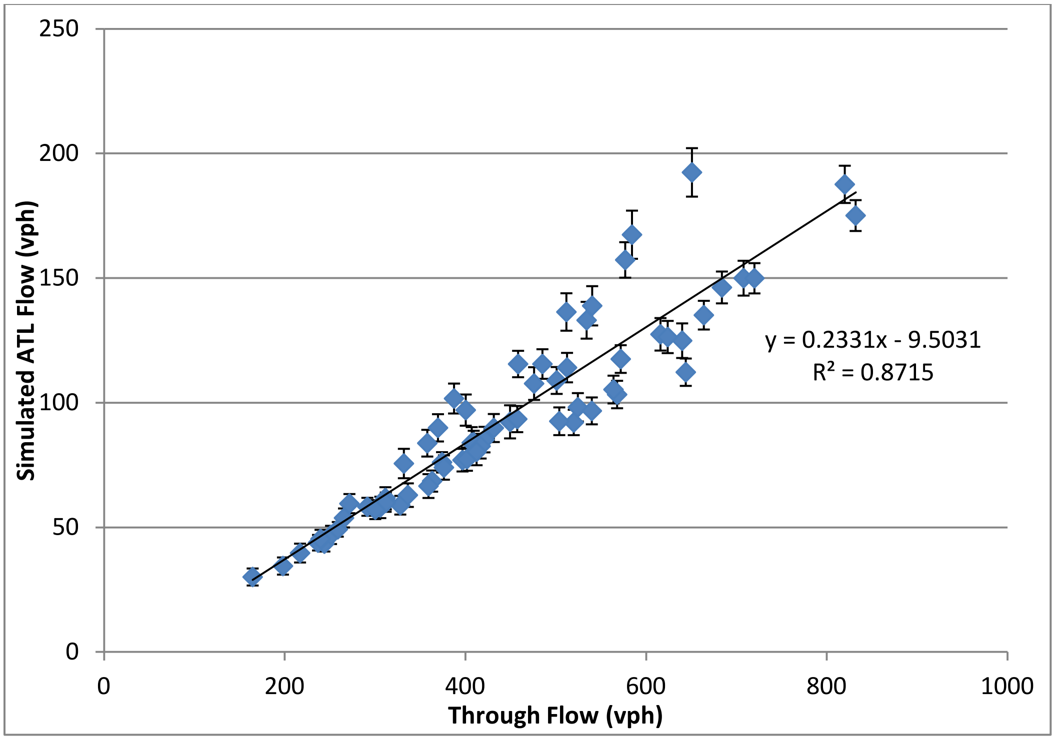


FIGURE 6-10. Simulated ATL Flow versus Through Flow

The figure indicates that a positive correlation is evident. Error bars show the 95% confidence interval for each data point—it should be noted that, due to the sample size of 50 runs, the standard error was generally low (less than 3 ATL vph) for each data point. The author also investigated the relationship between the simulated ATL flow and X_T, displayed in Figure 6-9.

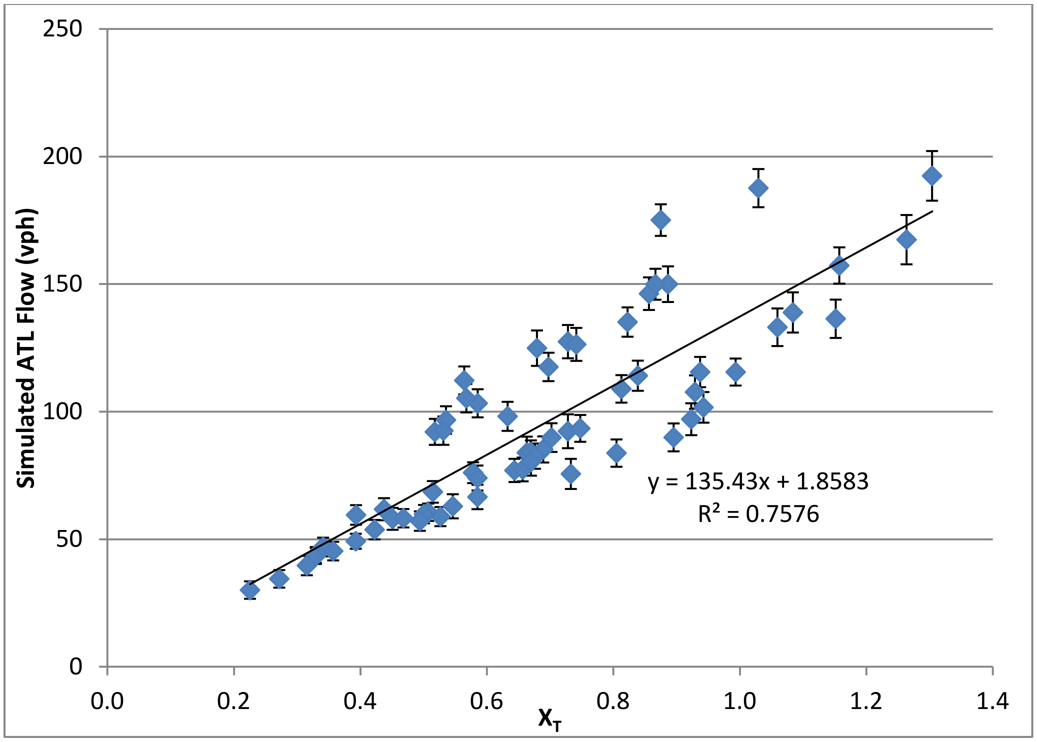


FIGURE 6-11. Simulated ATL Flow versus X_T

Figure 6-11 indicates a similarly increasing trend between ATL flow and X_T. Note that the simulated ATL flow tends to become more variable as the level of congestion (represented either as X_T or total through-movement flow) increases. Finally, the author investigated the relationship between the ATL flow simulated by the algorithm and several other input variables, including X_R, g/C, and cycle length, but no other trends were evident. It is interesting to note that the results of Chapter 3 showed that ATL flow exhibited a quadratic relationship with both total through-movement flow and X_T (see the 1-CTL plots in Figures 3-1 and 3-2), the relationships shown in Figures 6-10 and 6-11 are predominantly linear. The author was also interested in the amount of variability contained in the 50 simulation runs used to compute each data point for the purposes of model comparison. Although the error bars in Figures 6-10 and 6-11 yield some visualization of this variability, the author has presented a summary of the standard deviation for each data point in Appendix E.

Given the robustness of the simulation algorithm and the strength of the disaggregate model (Chapter 5), the author recommends implementing the disaggregate model in microsimulation through the use of a target lane algorithm. Figure 6-12 displays a pseudo-code flow chart that explains the methods for such implementation. The figure reflects a general case where a shared ATL is present, although the special case of an exclusive ATL may also be considered by setting the right turn demand equal to zero, much like the treatment in Figure 5-1.

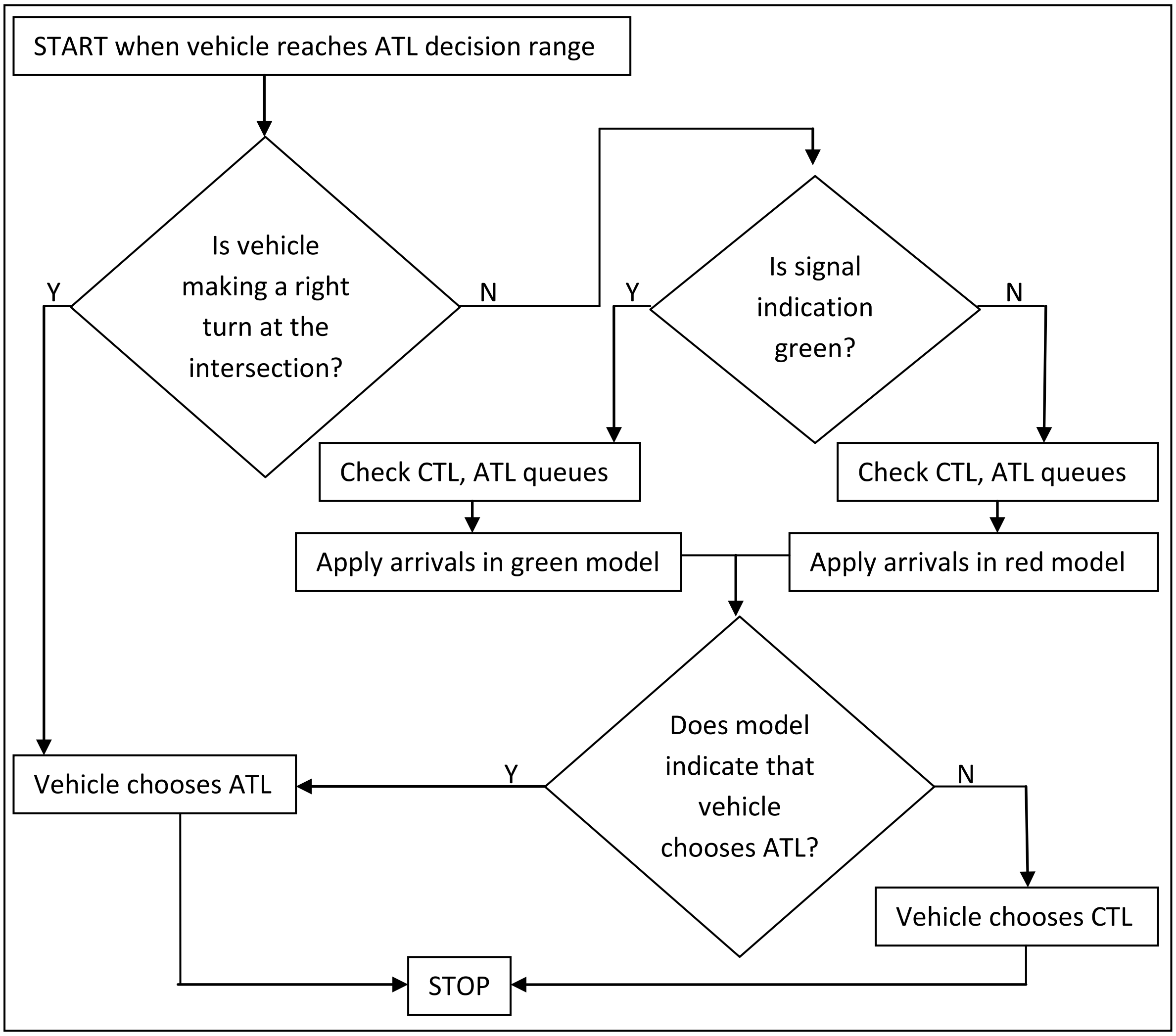


FIGURE 6-12. Pseudo-code for Disaggregate Model Implementation in Microsimulation

The flow chart indicates that, for each vehicle that reaches the *decision range*, an area that extends from the formation of the ATL taper to a point located 300 to 500 feet upstream of the intersection, the algorithm first checks to see if the vehicle is making a right turn (and then assigns the vehicle to the appropriate lane). This decision range is related to the decision point described in the disaggregate model development in Chapter 4, but it allows for an interval where simulated vehicles may choose to move into the ATL at multiple points upstream of the intersection. Then the algorithm checks the signal indication and applies the appropriate disaggregate model (for arrivals in red or green). Then, based on a comparison of a random number with the resulting probability of ATL use, the algorithm assigns the vehicle to either through-movement lane.

6.2.9 Summary of Microsimulation Implementation

The primary finding of this effort is that field-observed ATL utilization can be duplicated in microsimulation packages by altering the UDD of the ATL, allowing ATL operations to be more accurately modeled without forcing a particular utilization through routing decisions or some other means. Without changing the UDD parameter, the resulting ATL utilization will be subject to the tool-specific default, which will likely not result in accurate utilization effects. In fact, the parameter default in VISSIM for LCD is 656.2 feet (200 meters), which with a total ATL length of 1,000 corresponds to LCD% of 65.6%, which will likely overestimate the amount of traffic in the ATL. To assist simulation analysts, the author developed a straightforward model to predict the UDD to be used in simulation if no information regarding the ATL utilization were available. The estimation of UDD has been integrated in a proposed work flow to work jointly with the aggregate models. Although the author primarily used VISSIM to achieve the results described in this section, the findings can ultimately be expanded to other microsimulation systems.

The author's exploration of the simulation algorithm introduced in Chapter 5 indicates that, when used with the disaggregate models, the algorithm yields trends that are consistent with field observations. Specifically, the author found that the ATL flow predicted by the algorithm increased with X_T and through-movement flow. Although the algorithm did not appear sensitive to changes in X_R, the results presented in Chapter 5 are encouraging in that the algorithm was still able to produce a level of ATL use that is statistically indistinguishable from field data. Finally, the pseudo-code flow chart presented in this section indicates that the disaggregate models can also be implemented in microsimulation systems with the discussed algorithm.

7 CONCLUSIONS AND RECOMMENDATIONS

This chapter presents a summary of the research presented in this dissertation, as well as the author's principal findings and recommendations for future research on this topic.

7.1 Research Summary

Several researchers have investigated the operational effects of auxiliary through lanes (ATLs) on signalized intersections in an effort to investigate the tendency of the Highway Capacity Manual (HCM) to over-predict ATL use. In particular, the author's research in this dissertation supports the development of an ATL flow prediction model, either using an aggregate or disaggregate approach. The author defines the aggregate model as one that predicts the hourly flow rate in the ATL as a function of macroscopic elements collected over hourly or 15-minute intervals—these include flow rates, signal timing, and site design elements. Alternatively, a disaggregate model yields the probability that each individual driver will use the ATL based on instantaneous conditions observed at the driver's arrival at a decision point upstream of the intersection. These elements may include queue lengths, arrival time, arrival phase, and vehicle type. The methods and resulting models are presented in ways such that they can be implemented in the HCM and possibly microsimulation systems.

The objectives of this research were to both better understand how to model driver behavior at ATLs and explain the factors that influence ATL use. This investigation has ultimately led the author to produce several practical models for predicting ATL use. The research contribution includes the following:

- **Aggregate model development.** The author used a database of 22 1- and 2-CTL sites to develop aggregate models for ATL use. Separate models were developed for 1- and 2-CTL sites because of varying trends in the data. These models predicted the hourly flow rate in the ATL and indicated that this flow increased as the congestion along the approach increased. This congestion level was quantified by the variable X_T, which is the ratio of through-movement demand to capacity, ignoring the presence of the ATL. The ATL flow also increased with the raw through-movement demand along the approach (regardless of signal timing), and the flow decreased with increasing right turns, reflected by the variable X_R (the ratio of right turn demand to capacity, equal to zero for an exclusive right turn lane. Finally, the ATL flow was related to a variety of design factors that varied from site to site—these are described in the following section. Data were aggregated into 15-minute intervals to mitigate cycle-to-cycle fluctuations in demand, and the models explained 70 to 80 percent of the variability in the data. The author then discussed the models, arguing that the models were simple to use and applicable within the context of the HCM.

- **Disaggregate model development.** The author discussed the need for a more in-depth exploration of the factors that affect driver lane choice at ATLs because of driver behavior at ATLs that could not be accounted for with an aggregate model (e.g. queuing patterns, heavy vehicles, and right-turning vehicles). While the author was satisfied with the aggregate modeling effort because these models explained 70 to 80 percent of the variability in the data, the author also realized the need for a target lane model for the purpose of updating the lane change algorithms of microsimulation systems. Since the disaggregate model is an alternative modeling method, it would also serve to potentially validate the aggregate models. With a pool of eight ATL approaches, the author used the multinomial logit model to predict each driver's lane choice as a function of instantaneous elements observed at each driver's time of arrival at a decision point upstream of the intersection. The preferred models were dependent upon the arrival phase (effective red or green) and the queue lengths in either lane. The author then explored the accuracy and precision of these models by validating them with field data from an additional site from outside the dataset, and the models performed moderately well in this respect.
- **Model comparison.** The aggregate and disaggregate models were compared to investigate whether they would produce similar results. The author developed a method

to compare the two model forms using Monte Carlo simulation that contained the same form of input and output data for each type of model and used random numbers to simulate each vehicle's arrival time, turning movement, and lane choice (based upon the disaggregate models). A total of 50 simulations were completed for each of 65 15-minute intervals in the comparison dataset. A paired t-test was used to compare the model predictions with each other as well as the model predictions and field observations. The results of this exercise indicated that the aggregate and disaggregate models were statistically indistinguishable, and they were also statistically indistinguishable from the field data.

- **Research implementation.** The author first discussed how to implement the results of the aggregate model in both the HCM procedure for signalized intersection capacity analysis. Specifically, the author addressed the challenges of incorporating ATL operations into the HCM lane grouping procedure and adjusting the lane utilization factor, as well as developing a method to determine ATL use under actuated control and the appropriate upstream ATL length. Then the author explained how the aggregate models could be used in conjunction with microsimulation systems to model ATLs, chiefly by calibrating the upstream decision distance (UDD). Finally the author discussed the use of the simulation algorithm to demonstrate the disaggregate model and how it can be applied within microsimulation lane choice algorithms, ultimately providing a pseudo-code for implementation of the models.

The findings of this research are expected to provide guidance for researchers who wish to further investigate ATL design and operations, as well as the practitioner who wishes to implement the research in order to analyze existing or planned ATL facilities.

7.2 Principal Findings and Conclusions

The following is a discussion of the research contributions tied to the objectives listed in Section 1.1, complete with a detailed account of the research effort:

1. *Develop a method to explain ATL use as a function of macroscopic factors that can be implemented in the Highway Capacity Manual to supplement the current guidance on lane utilization at signalized intersections*.

   The author used a total of 52 hours of video data recorded at 22 sites from five U.S. states to develop aggregate models to predict the flow in the ATL. These models were based on macroscopic data aggregated over multiple signal cycles into 15-minute intervals. Approximately 19 percent of all through-movement vehicles used the ATL across all sites, although this utilization ranged from 5 to 40 percent on a site-to-site basis. Specifically, the models showed the following trends:

   - ATL flow along a 1-CTL approach increased with congestion, as quantified by the variable X_T, the ratio of through-movement demand to capacity, assuming the ATL does not exist. As this variable approaches 1.0, it becomes increasingly difficult for the signal to serve all through-movement demand on the approach in just the CTL, leading to the need for additional capacity (the ATL). Additionally, the relationship between X_T and ATL flow was indicated to be quadratic, with the coefficient being taken as 97.1 vph—this reflects an increase in ATL flow of 97.1 vph as X_T increases from 0 to 1.
   - ATL flow increased with through-movement flow—this was also shown to be a quadratic relationship, but with a coefficient of 0.000116 vph^{-1}. This indicates, for example, that an increase in through-movement flow from 0 to 300 vph will cause nine times as many vehicles to use the ATL (10.44 vph) as an increase in through-movement flow from 0 to 100 vph (1.16 vph), regardless of the signal timing on the approach. Furthermore, the model intercept was 20 to 30 vph (depending on the model), indicating that approximately one vehicle per signal cycle would use the ATL regardless of the level of congestion on the approach—this is consistent with field observation.
   - ATL flow decreased with right turns from a shared ATL, quantified by the variable X_R, the ratio of demand to capacity for the right turn movement. The coefficient of

-71.1 vph indicates that, for a shared ATL approach, an increase in X_R from 0 to 1.0 will result in a decrease in ATL flow of -71.1 vph. This also indicates that right turns have no quantifiable effect on ATL use if an exclusive right turn lane is provided ($X_R = 0$).

- Several design elements of an ATL approach were shown to be related to ATL use, although the author could not quantify many of these trends. In particular, higher ATL use appeared to be related to a higher posted speed limit, the presence of an exclusive right turn lane, access management (low driveway density) along the approach, signage of the ATL as a through-movement lane, and the provision of adequate sight distance from the stop bar. Each of these elements could be modified to potentially increase the ATL flow on an approach.
- Finally, achieving a moderate to high level of ATL use appeared to be dependent upon the arrival pattern at the intersection. The motivation for using the ATL is tied to queuing—consequently, a well-progressed approach (i.e. one with most arrivals during the green phase) provides drivers with little rationale for using the ATL. In fact, the author removed one site (MD-214) from the model calibration dataset because of this signal progression. This also indicates that a reduction in g/C (potentially reallocating the green time to other movements or approaches) may increase ATL flow.

These models supported the HCM by specifying that increasing congestion leads to increased ATL use, but they also supported the current literature by indicating that the HCM tends to over-predict the lane utilization in an ATL. Perhaps the most intriguing finding of this part of the research was that ATL flow and ATL downstream length are unrelated, which refutes the hypothesis of much of the current literature. The aggregate models developed by the author explained between 70 and 80 percent of the variability in the data.

2. *Develop a behavioral model to explain driver lane choice at ATLs as a function of instantaneous conditions observed by the driver upstream of the intersection.*

Using a 1.5 to 2-hour sample of field data at each of eight ATL approaches with one CTL, the author developed a set of disaggregate models to specify the probability of ATL use for each arriving driver at a point upstream of the intersection. The author used the logit form, which involves calibrating a model to specify the utility of using the ATL. The models were primarily dependent upon the following variables:

- First, drivers' motivation to use the ATL appeared to change depending on the arrival phase (red or green). Drivers who arrived in green appeared to have a greater base disutility of using the ATL than drivers who arrived in red (as indicated by an intercept term of -1.81 versus -1.67).
- The primary factor tied to the utility of the ATL was the queue length in either lane (the CTL and the ATL). In several of the models, however, the CTL queue appeared to be more significant, although this is likely because ATL queues tended to be shorter, and many vehicles in the dataset arrived at the intersection when there was no ATL queue at all (e.g. late in the green phase or early in the red phase). The CTL queue length coefficient ranged from 0.09 to 0.14, indicating that for each increase of one vehicle in the CTL queue, the odds of using the ATL would increase by a value ranging from $e^{0.09}$ to $e^{0.14}$, or an increase of 9 to 15 percent. Although this may not result in a consistent or easily-discernible queuing pattern like the one displayed in Figure 1-2, it still supports the hypothesis that driver lane choice at ATLs is heavily influenced by the queues in either lane. By considering the ATL queue, this trend also accounts for right turns from a shared ATL, as well as drivers who use the ATL to turn into a driveway downstream of the intersection (i.e. "captive" users).
- Arrivals during the green phase were also slightly related to the green time remaining in the signal cycle. The author assumed that much of the arriving traffic consisted of commuters that were moderately familiar with the signal timing at the intersection, so it is reasonable that the models would account for the remaining green time. An additional variable, time to clear intersection, was used to reflect the amount of green time remaining *after* the CTL queue clears (taking into account the saturation headway), which was shown to be slightly related to the utility of the ATL in one model.

The models explained driver lane choice with relatively few causal variables and accounted for 25 to 35 percent of the variability in the data. Although this indicates that not all factors were accounted for, the author was satisfied with the model goodness of fit given the difficulty in modeling human behavior. The author also found that the factors that influenced driver lane choice were consistent from site to site, but the magnitude of these factors and the base utility of each lane tended to vary somewhat from site to site, indicating that there may be site factors that influence the decision. However, the author could not explain why some sites had a higher base utility than others (e.g. because of site location, design elements, etc.). Since the author could neither explain why the base utility of the ATL was higher at some sites than at others nor specify an adjustment factor to allow for site-to-site differences in the models, the author felt justified in using the combined (all sites) models. The resulting models were partially validated with data from a site outside the original dataset as follows:

- Accuracy validation. The expected number of ATL users under each model was determined for the validation site by calculating the probability of ATL use for each vehicle and then summing the probabilities over all vehicles. Then the expected number of ATL users was compared to the actual number of ATL users, and the error was shown to be between 15 and 25 percent. This indicates that the models were not extremely accurate but nonetheless still resulted in a realistic (i.e. not extremely low or high) level of ATL use.
- Precision validation. Another validation exercise examined how the field ATL utilization compared with the predicted probability of ATL use when these probabilities were grouped into intervals of 5%. The exercise found that, for several of the models, the ATL utilization tended to increase as the model predicted a higher probability of ATL use, which indicates that these models were successful in predicting trends in the field data.

These methods provided a more fundamental investigation of driver behavior at ATLs than those used to develop the aggregate models, and they provide models that can be incorporated into microsimulation systems to improve or replace current lane change algorithms that may result in an unrealistic level of simulated ATL use.

3. *Develop a method to compare the aggregate and disaggregate models and determine whether the models yield statistically indistinguishable results*.

   These methods can be summarized in the following steps:

   - The author recalibrated the aggregate model to reflect only the data used to develop the disaggregate model. This resulted in the same eight sites being used to calibrate both model types.
   - The author developed a simulation algorithm to compare the two model forms. Using random numbers, the author generated the arrival time and desired movement (through or right turn) for each arriving vehicle within a 15-minute period of simulation and then determined the probability of ATL use based on the disaggregate models and arrival phase. Then another random number was used to determine the lane choice of each vehicle, and the results were combined for each observation within the 15-minute period. Then the author repeated the procedure for 50 iterations and for each 15-minute data point in the dataset, which consisted of 65 such data points.
   - The models were compared using a paired difference t-test, and the results indicated that the model predictions were statistically indistinguishable at the 0.05 significance level. Using the same test, the author also concluded that the aggregate and disaggregate model predictions were statistically indistinguishable from the field data at the 0.05 significance level.

The key finding of this research is that the aggregate model is validated by the disaggregate model and that both models are validated by the field data. However, given the success and simplicity of the aggregate model, the question remains whether the disaggregate model is necessary. Although the comparison methodology is sound and the two models were found to be equivalent, the author recommends using the disaggregate model only for purposes of microsimulation—otherwise the aggregate model should be used. The author's simulation algorithm to compare the two model types is also a principal contribution to current practice.

4. *Develop a method to implement the results of the research into current engineering practice.*

   The author implemented the results of the research in two forms: updating the HCM procedure to reflect the aggregate models for ATL use and also specifying a method to analyze ATLs using microsimulation systems, whether by calibrating the current model to predict the correct level of ATL use or by updating the lane assignment algorithm to be consistent with the disaggregate model. The first implementation task involved the following three challenges:

   - Incorporating the aggregate models into the HCM signalized intersection procedure but not specifying an ATL flow that would exceed the HCM prediction using the current equal v/s approach,
   - Determining the ATL upstream length that would allow for unobstructed access to all lanes on the approach, and
   - Addressing actuated signal control by balancing ATL use with the green time allocated to the ATL approach.

   The principal finding of this portion of the research was that the author could address each of these challenges in the following ways:

   - The author accounted for the current HCM lane utilization factor by specifying an upper bound to the aggregate models based upon an equal degree of saturation in each lane. With such an upper bound, the models no longer predict an ATL utilization that is greater than the current HCM recommendation, which has already been found to be unrealistically high.
   - The upstream ATL length was recommended to be set at the 95th percentile queue for

the ATL or CTL(s), whichever is greater. This mitigates a potential blockage event, where vehicles are denied access to all lanes because of queue spillback.

- Finally, the author developed a pseudo-code to visualize a procedure to incorporate actuated signal control into the ATL flow prediction models. This was necessary because, under actuated control, an increase in ATL use will lead to a reduction in available green time, but this will in turn increase X_T (as used in the models), leading to an increase in ATL use. This necessitates an iterative procedure which is repeated until the process reaches equilibrium, which occurs when the ATL flow in successive iterations is within a specified threshold.

These findings are demonstrated in two example problems that are similar to those presented in the HCM 2010. The author also addressed ATL modeling within microsimulation systems by finding that ATL use is principally controlled by the upstream decision distance parameter. The key contribution here is a method to accurately calibrate a microsimulation network to achieve the desired level of ATL use. Finally, the author presented and investigated an algorithm that can be used to simulate ATL use at the microscopic level based on a set of three random number draws:

i. First the algorithm uses a random number to determine the arrival time of each successive vehicle based upon an exponential distriabution.
ii. Then another random number is used to determine the vehicle routing decision (through or right turn, assuming a shared ATL is present). If an exclusive right turn lane is provided, then no random number draw is necessary.
iii. A final random number is used in conjunction with the appropriate disaggregate model (red or green based upon the current signal phase when the vehicle reaches the decision point) to determine the vehicle’s lane choice.

The author then described this methodology using a pseudo-code flow chart appropriate for microsimulation systems.

7.3 Recommendations for Future Research

Although each of the research contributions described in Section 1.1 has been fulfilled by the author, there are many other applications for which the research here can be used. The most general suggestion for future research is to use the methods described here but test their validity to similar facilities not covered within the scope of this research. These include, but are not limited to, the following designs:

- A lane drop beyond a signalized intersection that ends in an exclusive right turn lane (as opposed to a conventional merge like the one in the scope of this research),
- A continuous lane upstream of an intersection that ends in a merge beyond the intersection,
- Dual left turn lanes that merge into a single lane beyond the intersection,
- Similar facilities that begin or end on the left-hand side of an arterial before or after a signalized intersection, and
- Auxiliary lanes on a roundabout approach.

While they contain auxiliary lanes, the subtle design elements of these facilities may cause them to operate significantly differently than the ATLs described in this research. However, the frequency of these other designs may necessitate separate models or design guidelines so that they may also be explored to the same extent as the ATLs described here.

Additionally, the datasets used in this research could be expanded. Although the full 22-site dataset contained in Table 1-1 is arguably comprehensive, there may be combinations of ATL type, number of CTLs, and congestion levels at other sites that, if analyzed, could alter the resulting aggregate models. The same is true for the disaggregate models, which were only based upon eight 1-CTL sites and ultimately exhibited statistically different results with the exclusion of one or multiple sites from the calibration dataset. The author suggests using the methods described here to develop more disaggregate models under a larger, more comprehensive dataset, particularly one that exhibits a high number of arrivals in both the red phase and the green phase. The author also suggests developing disaggregate models for 2-CTL sites, although the MNL model and its assumptions may become considerably more complex, as there would be three lane choices instead of two, and there may be some nesting involved (i.e. each driver must choose between the ATL and CTLs and then, if the ATL is not chosen, choose between either of the CTLs). Such a model, if developed, could potentially explain much of the variability in the 2-CTL data, which appeared to be considerably more variable than the 1-CTL data (Figures 3-1 and 3-2).

Many of the operational and site design factors hypothesized to influence ATL use could be tested in the field in the form of a controlled experiment. For example, the research has shown that higher ATL use is related to a higher degree of congestion (X_T), but a causal relationship could be investigated in the field by varying the green time on an ATL approach. With permission from a local agency, the experimenter could measure the ATL flow under similar conditions with a low g/C and a high g/C and then quantify the relationship. Likewise, although this research has shown that downstream ATL length is unrelated to ATL use, the experimenter could test this in the field (again, with local agency permission) through the use of barrels or cones to effectively shorten the ATL downstream length. An additional experiment could examine the effect of various signage (e.g. upstream or overhead signage of the ATL as a through-movement lane, upstream signage that warns of a lane-drop beyond the intersection, or the use of the zipper / alternate merge in the ATL) on ATL use.

The author also proposes a validation exercise that would compare the resulting disaggregate models to travel time or delay data from the field. This process would involve collecting the travel time or delay of each vehicle that passed through the intersection and then comparing the delay to ATL users with the delay to CTL users. This comparison could also include an investigation of the disaggregate model output and whether the models predicted a higher probability of ATL use for those vehicles that incurred higher delay from using the CTL, much like the precision validation effort presented in Table 4-8. While the author used an exponential distribution to simulate the disaggregate models in order for them to be compared with the aggregate model, it is also possible to use the empirical distribution (i.e. actual field-observed arrival times) to simulate these disaggregate models. Finally, the author recommends more research on the subject of implementing target lane algorithms in microsimulation systems so that they may more accurately model driver behavior, not only at ATL facilities but on arterials in general. Some of the literature described in Chapter 2 has indicated that a few studies related to using utility models for these target lane algorithms are already underway.

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APPENDICES

A SITE DESCRIPTIONS

The following is a description of each site common to the datasets used to develop the aggregate and disaggregate models. These sites are listed in Table 4-1.

1. NC-54 at Fayetteville Road

Eastbound NC-54 at Fayetteville Road in Durham is a busy intersection of two arterials that is located near one of the region's largest shopping centers (Streets of Southpoint). An interchange with Interstate 40 lies just to the south along Fayetteville Road. This approach is unique for two reasons: first, the upstream ATL length is much longer than the other 1-CTL sites (1,650 feet) and runs over many driveways (Figure A-1). Because of these conditions the extreme upstream portion of the ATL is used mainly as a right-turn lane for these driveways—most drivers who intend to use the ATL all the way through the intersection do not enter the lane until the last set of driveways (see Figure A-1). To account for this observation and the complications arising from the driveways upstream of the intersection, the analyst placed the upstream camera at the last set of driveways before the intersection.

FIGURE A-1. Aerial Photo of NC-54 at Fayetteville Road (*40*)

The other unique characteristic of this ATL is the downstream underpass at Interstate 40 (Figure A-2). At 450 feet, the downstream portion of the ATL is sufficiently long enough to allow safe merging behavior as indicated from field observation. However, the analyst hypothesized that the downstream underpass and structure adjacent to the roadway creates a constrained environment that may cause some drivers to feel less comfortable with using the ATL for fear of crashing into the guardrail or underpass structure.

FIGURE A-2. Underpass Downstream of ATL Merge (*40*)

In spite of this hypothesis, it appeared that drivers were perfectly willing to use the ATL. The average ATL utilization observed over the course of data collection at this site was 23 percent, the highest observed at any of the North Carolina sites. The analysts also recorded more video data at this site than at any other. The only limitation of the data at this site was the tendency of drivers to make last-minute lane changes at the intersection, even while queued. This was presumably caused by driver unfamiliarity, which could be attributed to the site's location near multiple shopping centers (i.e. less commuter traffic). This late lane-changing may cause some frustration during data extraction, but it should be noted that the analyst recorded each driver's *initial* lane choice, regardless of last-minute lane changes upstream of the signal. In spite of this deficiency, the volume of data collection, the relatively high ATL use, and the presence of driveways upstream and downstream of the intersection (which allow more captive drivers to be observed) made this site exceptional for inclusion into the dataset for a microscopic study.

The NC-54 site also provided a great example of the observed queuing pattern that initially led the author to investigate driver lane choice at ATLs (see Figure A-2). Although this exact pattern was not observed during every cycle recorded at the NC-54 site, it is probable that there is some underlying pattern that indicates how large a queue differential (or ratio, as in this case) must be in order for an approaching driver to choose the ATL.

2. Garrett Road at Old Chapel Hill Road

Garrett Road at Old Chapel Hill Road in Durham, NC consists of two ATL approaches—one northbound and one southbound. Each approach has one CTL and an exclusive ATL. From field observation the author noticed that drivers were more reluctant to use these ATLs than the NC-54 site, but a queuing pattern still emerged: at least one driver would use the ATL nearly anytime that the CTL queue extended beyond three vehicles. This in combination with the short green time for the ATL approaches allowed ATL users to save a significant amount of travel time. It was also interesting to observe driver behavior when a bus used the ATL—subsequent drivers would almost always use the CTL to avoid getting stuck behind the bus. Figure A-3 displays an aerial photo of the two approaches.

FIGURE A-3. Garrett Road at Old Chapel Hill Road (*40*)

The topography of this intersection makes it ideal for data collection—as the intersection lies on the side of a hill and both ATLs are short, cameras placed at either end can view the entirety of the two approaches.

3. La Cañada Drive at Magee Road

The intersection of La Cañada Dr and Magee Rd in Tucson, AZ, is particularly useful to the author because it contains four ATLs—one for each leg of the intersection, as displayed in Figure A-4.

FIGURE A-4. La Cañada Drive at Magee Road (*40*)

The site was also useful because it contained very few driveways, very streamlined tapers, and good site distance from end to end. All approaches are shared ATLs, and the coordinated system on the main approach (La Cañada Drive) allowed the author to observe more arrivals in green than at other sites. The author also observed that, in spite of the long downstream ATL length and tapers (over 700 feet), ATL users tended to travel the entire downstream length of the ATL to accelerate to the posted speed (45 mph), even when there were no opposing vehicles in the CTL. Finally, it should be noted that since the data were collected, La Cañada Drive has been fully widened on both sides of the intersection, indicating that ATLs are truly an interim improvement, particularly in fast-growing areas such as Tucson.

4. Walker Road at 185th Avenue

Walker Road contains two ATL approaches at 185th Avenue in Beaverton, OR, one of which (the eastbound approach) was studied in this research because it contained an exclusive ATL and the line of sight was sufficient for good camera placement. Figure A-5 displays an aerial image of the site.

FIGURE A-5. Walker Road at 185th Avenue (*40*)

This site is notable for its extremely short ATL length (960 feet from end to end) but high average ATL utilization (40 percent). The author noticed that the green time was short for this site and may have been reduced as a result of the presence of the ATL.

5. Walker Road at Murray Boulevard

Figure A-6 displays an aerial image of the Walker Road at Murray Boulevard site in Beaverton, Oregon. Only the westbound approach was included in the disaggregate models and model comparison, but both directions were used in the development of the aggregate models in Chapter 3.

FIGURE A-6. Walker Road at Murray Boulevard (*40*)

B FIELD DATA

The following tables list the raw data used to develop the aggregate and disaggregate models, as well as a summary of the simulation runs used for the model comparison. Table B-1 lists each 15-minute interval of field data used to develop the full aggregate models described in Chapter 3 as well as the reduced aggregate model described in Chapter 5. The table lists the following elements:

- Approach name;
- Effective green time, in seconds, represented as the actual green time (for coordinated approaches) or the maximum effective green time (for actuated approaches);
- Cycle length, in seconds;
- The number of cycles recorded in the 15-minute interval;
- The observed number of passenger cars and heavy vehicles in the CTL;
- The observed number of passenger cars and heavy vehicle in the ATL;
- The observed number of right-turning passenger cars and heavy vehicles (regardless of whether the approach is equipped with an exclusive right turn lane);
- ATL utilization, expressed as a percentage of total through-movement demand;
- The percentage of observed through and right traffic that turned right;
- X_T
- ATL flow rate (in vph);
- Total through-movement flow rate (in vph);
- Saturation headway (in pcphpl); and
- X_R.

Table B-2 lists the raw data used to develop the disaggregate model—in this case, each row represents an individual vehicle. The table lists the location of each observation, the vehicle ID (an arbitrary number assigned to organize each observation), a binary variable denoting whether the vehicle used the ATL (0=CTL, 1=ATL), the CTL and ATL queues (in number of vehicles) at the time of arrival, the difference in these queues (CTL minus ATL), as well as the following three variables:

- The arrival time in seconds after the start of the red phase (listed only for vehicles arriving in red);
- The green time remaining in the cycle (in seconds), listed only for vehicles arriving in green;
- G-hq, which is the green time remaining minus the product of the saturation headway (assumed to be two seconds) and the CTL queue (in vehicles). This is also denoted the “Time to Clear Intersection” in Chapter 4.

Table B-3 lists the data used to compare the aggregate and disaggregate models.

TABLE B-1. 15-minute Interval Field Data for Aggregate Model

Approach	(Max) effective green time (s)	Cycle Length (s)	# Cycles	CTL Cars	CTL Trucks	ATL Cars	ATL Trucks	Right Turn Cars	Right Turn Trucks	ATL Utilization (%)	% Right Turns	X_T	ATL Flow (vph)	Through Flow (vph)	Saturation Headway (pcphpl)	X_R
EB Walker at Murray	350	888	10	66	1	31	1	11	0	32	10	0.50	129.7	401.4	1.77	0.07
EB Walker at Murray	350	883	10	90	0	32	1	23	1	27	16	0.62	134.5	501.5	1.77	0.14
EB Walker at Murray	350	954	10	105	1	50	1	35	1	32	19	0.79	192.5	592.5	1.77	0.21
EB Walker at Murray	350	1001	10	102	0	38	1	45	0	28	24	0.71	140.3	507.1	1.77	0.27
EB Walker at Murray	350	970	10	94	0	24	1	31	1	21	21	0.60	92.8	441.6	1.77	0.19
EB Walker at Murray	350	982	10	96	0	31	2	32	2	26	21	0.65	121.0	472.9	1.77	0.20
EB Walker at Murray	350	912	10	63	1	23	0	31	0	26	26	0.44	90.8	343.4	1.77	0.18
EB Walker at Murray	350	929	10	83	1	20	2	31	0	21	23	0.54	85.3	410.8	1.77	0.18
EB Walker at Murray	350	913	10	117	0	44	4	56	5	29	27	0.83	189.3	650.6	1.77	0.36
EB Walker at Murray	350	1016	10	125	2	35	1	65	1	22	29	0.82	127.6	577.6	1.77	0.39
EB Walker at Murray	350	925	10	129	2	47	1	49	1	27	22	0.90	186.8	696.6	1.77	0.30
EB Walker at Murray	350	955	10	131	5	59	2	29	0	31	13	1.00	229.9	742.6	1.77	0.17
EB Walker at Murray	350	1019	10	163	0	76	0	51	1	32	18	1.21	268.5	844.4	1.77	0.31
EB Walker at Murray	350	948	10	162	1	86	0	48	0	35	16	1.26	326.6	945.6	1.77	0.29
EB Walker at Murray	357	1000	10	130	0	54	1	51	1	30	22	0.92	198.0	666.0	1.77	0.30
WB Walker at Murray	217	862	7	77	1	36	0	26	0	32	19	0.93	150.3	476.1	1.77	0.25
WB Walker at Murray	217	886	7	97	1	44	0	15	1	31	10	1.16	178.8	577.0	1.77	0.15
WB Walker at Murray	217	853	7	88	0	26	1	30	0	23	21	0.94	114.0	485.3	1.77	0.29
WB Walker at Murray	217	876	7	92	0	38	0	25	0	29	16	1.06	156.2	534.2	1.77	0.24
WB Walker at Murray	217	886	7	91	0	42	0	25	0	32	16	1.08	170.7	540.4	1.77	0.24
WB Walker at Murray	217	885	7	115	0	43	2	26	1	28	14	1.30	183.1	650.8	1.77	0.26

Approach	(Max) effective green time (s)	Cycle Length (s)	# Cycles	CTL Cars	CTL Trucks	ATL Cars	ATL Trucks	Right Turn Cars	Right Turn Trucks	ATL Utilization (%)	% Right Turns	X_T	ATL Flow (vph)	Through Flow (vph)	Saturation Headway (pcphpl)	X_R
NC 54	260	2005	10	95	2	30	1	165	2	24	57	0.97	55.7	229.8	1.96	0
NC 54	260	1003	10	50	0	15	0	70	1	23	52	0.49	53.8	233.3	1.96	0
NC 54	260	996	10	37	1	9	0	70	0	19	60	0.35	32.5	169.9	1.96	0
NC 54	260	1006	10	65	1	23	0	98	1	26	53	0.67	82.3	318.5	1.96	0
NC 54	260	1000	10	60	3	22	0	87	0	26	51	0.64	79.2	306.0	1.96	0
NC 54	260	1108	10	65	2	18	0	98	2	21	54	0.64	58.5	276.2	1.96	0
NC 54	260	1093	10	70	1	13	0	92	0	15	52	0.63	42.8	276.7	1.96	0
NC 54	260	1105	10	73	0	19	1	114	0	22	55	0.70	65.2	303.0	1.96	0
NC 54	260	915	10	69	2	23	0	97	0	24	51	0.71	90.5	369.8	1.96	0
NC 54	260	917	10	82	2	29	0	105	1	26	48	0.85	113.8	443.6	1.96	0
NC 54	260	922	10	88	1	32	0	105	1	26	47	0.91	124.9	472.5	1.96	0
NC 54	260	911	10	76	0	25	0	109	4	25	53	0.76	98.8	399.1	1.96	0
NB La Canada at Magee	366	851	10	104	1	19	0	21	0	15	14	0.63	80.4	524.6	1.87	0.13
NB La Canada at Magee	395	900	10	132	1	21	0	12	0	14	7	0.73	84.0	616.0	1.87	0.07
NB La Canada at Magee	383	900	10	115	0	28	0	21	0	20	13	0.70	112.0	572.0	1.87	0.12
NB La Canada at Magee	377	900	10	135	0	31	0	23	0	19	12	0.82	124.0	664.0	1.87	0.13
NB La Canada at Magee	372	900	10	154	0	49	2	30	0	25	13	1.03	204.0	820.0	1.87	0.18
NB La Canada at Magee	373	900	10	138	0	32	1	32	1	19	16	0.86	132.0	684.0	1.87	0.19
NB La Canada at Magee	373	900	10	145	3	28	1	21	1	16	11	0.89	116.0	708.0	1.87	0.13
NB La Canada at Magee	444	900	10	166	0	42	0	21	0	20	9	0.88	168.0	832.0	1.87	0.10
NB La Canada at Magee	388	900	10	141	0	39	0	29	0	22	14	0.87	156.0	720.0	1.87	0.16

Approach	(Max) effective green time (s)	Cycle Length (s)	# Cycles	CTL Cars	CTL Trucks	ATL Cars	ATL Trucks	Right Turn Cars	Right Turn Trucks	ATL Utilization (%)	% Right Turns	X_T	ATL Flow (vph)	Through Flow (vph)	Saturation Headway (pcphpl)	X_R
SB La Canada at Magee	533	900	10	134	5	22	0	34	2	14	18	0.56	88.0	644.0	1.87	0.15
SB La Canada at Magee	471	900	10	110	0	25	0	38	1	19	22	0.54	100.0	540.0	1.87	0.18
SB La Canada at Magee	440	900	10	129	0	30	1	42	0	19	21	0.68	124.0	640.0	1.87	0.21
SB La Canada at Magee	393	900	10	123	1	32	0	45	1	21	23	0.74	128.0	624.0	1.87	0.26
SB La Canada at Magee	469	900	10	114	2	13	1	38	0	11	23	0.52	56.0	520.0	1.87	0.18
SB La Canada at Magee	453	900	10	116	5	20	1	34	0	15	19	0.59	84.0	568.0	1.87	0.16
SB La Canada at Magee	443	900	10	101	5	19	1	29	1	16	19	0.53	80.0	504.0	1.87	0.15
SB La Canada at Magee	464	900	10	100	3	38	0	23	0	27	14	0.57	152.0	564.0	1.87	0.11

Approach	(Max) effective green time (s)	Cycle Length (s)	# Cycles	CTL Cars	CTL Trucks	ATL Cars	ATL Trucks	Right Turn Cars	Right Turn Trucks	ATL Utilization (%)	% Right Turns	X_T	ATL Flow (vph)	Through Flow (vph)	Saturation Headway (pcphpl)	X_R
EB Magee at La Canada	290	900	10	60	2	16	0	9	2	21	12	0.51	64.0	312.0	1.89	0.08
EB Magee at La Canada	290	889	10	68	0	13	0	15	2	16	17	0.53	52.6	328.0	1.89	0.13
EB Magee at La Canada	290	902	10	81	1	20	0	9	1	20	9	0.66	79.8	407.1	1.89	0.08
EB Magee at La Canada	290	906	10	99	3	27	0	10	0	21	7	0.84	107.3	512.6	1.89	0.08
EB Magee at La Canada	290	889	10	56	1	15	0	7	0	21	9	0.47	60.7	291.6	1.89	0.05
EB Magee at La Canada	290	906	10	84	2	20	0	11	0	19	9	0.69	79.5	421.2	1.89	0.08
EB Magee at La Canada	290	897	10	91	2	19	0	10	0	17	8	0.73	76.3	449.5	1.89	0.08
EB Magee at La Canada	290	898	10	72	5	22	0	13	0	22	12	0.64	88.2	396.9	1.89	0.10
EB Magee at La Canada	290	906	10	86	0	17	0	9	0	17	8	0.67	67.5	409.3	1.89	0.07
EB Magee at La Canada	290	898	10	105	2	18	0	4	0	14	3	0.81	72.2	501.1	1.89	0.03
EB Magee at La Canada	290	905	10	76	0	25	0	4	0	25	4	0.66	99.4	401.8	1.89	0.03
EB Magee at La Canada	290	898	10	87	0	16	1	7	0	16	6	0.68	68.2	416.9	1.89	0.05
EB Magee at La Canada	290	901	10	90	0	17	1	7	1	17	7	0.70	71.9	431.5	1.89	0.06

Approach	(Max) effective green time (s)	Cycle Length (s)	# Cycles	CTL Cars	CTL Trucks	ATL Cars	ATL Trucks	Right Turn Cars	Right Turn Trucks	ATL Utilization (%)	% Right Turns	X_T	ATL Flow (vph)	Through Flow (vph)	Saturation Headway (pcphpl)	X_R
WB Magee at La Canada	290	899	10	89	0	14	0	57	0	14	36	0.67	56.1	412.5	1.89	0.44
WB Magee at La Canada	290	905	10	100	0	14	1	34	0	13	23	0.75	59.7	457.5	1.89	0.26
WB Magee at La Canada	290	902	10	73	1	16	0	41	2	18	32	0.59	63.9	359.2	1.89	0.33
WB Magee at La Canada	290	899	10	70	0	14	0	26	1	17	24	0.55	56.1	336.4	1.89	0.21
WB Magee at La Canada	290	861	10	75	0	15	0	42	0	17	32	0.59	62.7	376.3	1.89	0.32
WB Magee at La Canada	290	889	10	66	2	9	0	45	0	12	37	0.50	36.4	311.8	1.89	0.34
WB Magee at La Canada	290	911	10	69	0	7	0	46	0	9	38	0.49	27.7	300.3	1.89	0.35

Approach	(Max) effective green time (s)	Cycle Length (s)	# Cycles	CTL Cars	CTL Trucks	ATL Cars	ATL Trucks	Right Turn Cars	Right Turn Trucks	ATL Utilization (%)	% Right Turns	X_T	ATL Flow (vph)	Through Flow (vph)	Saturation Headway (pcphpl)	X_R
NB La Canada at Orange Grove	310	812	7	66	2	19	0	14	0	22	14	0.57	84.2	385.7	2.02	0.11
NB La Canada at Orange Grove	374	840	7	66	0	19	0	12	1	22	13	0.46	81.4	364.3	2.02	0.08
NB La Canada at Orange Grove	323	846	7	66	1	17	0	26	1	20	24	0.53	72.3	357.4	2.02	0.20
NB La Canada at Orange Grove	327	840	7	74	0	15	0	19	1	17	18	0.55	64.3	381.4	2.02	0.15
NB La Canada at Orange Grove	341	834	7	76	0	11	0	19	0	13	18	0.52	47.5	375.5	2.02	0.13
NB La Canada at Orange Grove	383	846	7	100	1	13	0	24	0	11	17	0.60	55.3	485.1	2.02	0.15
NB La Canada at Orange Grove	320	840	7	82	0	23	0	19	0	22	15	0.66	98.6	450.0	2.02	0.14
NB La Canada at Orange Grove	356	840	7	91	0	21	0	30	0	19	21	0.64	90.0	480.0	2.02	0.20
NB La Canada at Orange Grove	349	835	7	105	1	35	0	23	0	25	14	0.82	150.9	607.9	2.02	0.16
NB La Canada at Orange Grove	339	845	7	82	1	25	0	31	0	23	22	0.64	106.5	460.1	2.02	0.22
NB La Canada at Orange Grove	378	841	7	79	2	22	0	20	0	21	16	0.55	94.2	440.9	2.02	0.13
NB La Canada at Orange Grove	404	840	7	75	0	17	0	22	1	18	20	0.46	72.9	394.3	2.02	0.14
NB La Canada at Orange Grove	399	840	7	94	0	20	0	25	0	18	18	0.58	85.7	488.6	2.02	0.15

Approach	(Max) effective green time (s)	Cycle Length (s)	# Cycles	CTL Cars	CTL Trucks	ATL Cars	ATL Trucks	Right Turn Cars	Right Turn Trucks	ATL Utilization (%)	% Right Turns	X_T	ATL Flow (vph)	Through Flow (vph)	Saturation Headway (pcphpl)	X_R
SB La Canada at Orange Grove	401	835	7	62	0	15	0	34	1	19	31	0.37	64.7	332.0	1.91	0.20
SB La Canada at Orange Grove	377	845	7	62	0	20	0	48	2	24	38	0.41	85.2	349.3	1.91	0.30
SB La Canada at Orange Grove	407	841	7	64	0	10	1	40	0	15	35	0.35	47.1	321.0	1.91	0.22
SB La Canada at Orange Grove	413	840	7	54	1	13	0	31	0	19	31	0.31	55.7	291.4	1.91	0.17
SB La Canada at Orange Grove	473	840	7	62	3	15	0	26	1	19	25	0.32	64.3	342.9	1.91	0.13
SB La Canada at Orange Grove	420	840	7	65	1	14	0	30	2	18	29	0.36	60.0	342.9	1.91	0.17
EB Walker at 185	204	855	7	56	0	28	1	47	1	34	36	0.81	122.1	357.9	1.93	0.00
EB Walker at 185	203	835	7	49	0	28	0	41	0	36	35	0.73	120.7	332.0	1.93	0.00
EB Walker at 185	205	925	7	57	1	36	1	61	3	39	40	0.90	144.0	369.7	1.93	0.00
EB Walker at 185	205	929	7	56	1	43	0	64	0	43	39	0.94	166.6	387.5	1.93	0.00
EB Walker at 185	211	850	7	82	0	54	2	75	1	41	36	1.26	237.2	584.5	1.93	0.00
EB Walker at 185	212	856	7	65	0	44	0	72	0	40	40	0.99	185.0	458.4	1.93	0.00
EB Walker at 185	203	851	7	68	0	53	0	65	1	44	35	1.15	224.2	511.9	1.93	0.00
EB Walker at 185	203	872	7	57	1	39	0	44	0	40	31	0.92	161.0	400.5	1.93	0.00

Approach	(Max) effective green time (s)	Cycle Length (s)	# Cycles	CTL Cars	CTL Trucks	ATL Cars	ATL Trucks	Right Turn Cars	Right Turn Trucks	ATL Utilization (%)	% Right Turns	X_T	ATL Flow (vph)	Through Flow (vph)	Saturation Headway (pcphpl)	X_R
WB Walker at 185	221	876	8	56	1	9	0	47	0	14	42	0.58	37.0	271.2	1.93	0.48
WB Walker at 185	248	838	8	91	0	16	0	46	0	15	30	0.83	68.7	459.7	1.93	0.42
WB Walker at 185	248	780	8	53	0	8	0	42	2	13	42	0.48	36.9	281.5	1.93	0.40
WB Walker at 185	248	925	8	71	0	12	0	58	0	14	41	0.65	46.7	323.0	1.93	0.53
WB Walker at 185	256	875	8	58	1	12	0	44	0	17	38	0.54	49.4	292.1	1.93	0.39
WB Walker at 185	248	935	8	80	1	16	0	57	0	16	37	0.76	61.6	373.5	1.93	0.52
Sunset Lake	336	702	8	52	0	7	1	16	0	13	21	0.37	41.0	307.7	2.04	0.11
Sunset Lake	336	902	8	74	2	10	0	17	1	12	17	0.52	39.9	343.2	2.04	0.13
Sunset Lake	336	931	8	92	0	3	0	28	0	3	23	0.58	11.6	367.3	2.04	0.20
Sunset Lake	336	1077	8	102	0	9	0	26	1	8	20	0.68	30.1	371.0	2.04	0.19
Sunset Lake	336	922	8	83	0	6	0	29	0	7	25	0.54	23.4	347.5	2.04	0.21
NB Garrett	336	854	7	37	0	9	1	63	1	21	58	0.27	42.2	198.1	1.94	0
NB Garrett	336	918	7	65	1	12	0	88	1	15	53	0.45	47.1	305.9	1.94	0
NB Garrett	336	962	7	87	0	13	0	78	0	13	44	0.58	48.6	374.2	1.94	0
NB Garrett	336	901	7	56	1	10	1	78	0	16	53	0.39	44.0	271.7	1.94	0
NB Garrett	336	882	7	67	1	21	0	152	3	24	64	0.51	85.7	363.3	1.94	0
NB Garrett	336	841	7	42	3	12	0	160	1	21	74	0.33	51.4	244.0	1.94	0
NB Garrett	336	866	7	43	2	12	0	134	3	21	71	0.33	49.9	237.0	1.94	0
NB Garrett	336	853	7	32	1	6	0	122	1	15	76	0.23	25.3	164.6	1.94	0
NB Garrett	336	845	7	51	0	8	0	139	2	14	71	0.34	34.1	251.4	1.94	0

Approach	(Max) effective green time (s)	Cycle Length (s)	# Cycles	CTL Cars	CTL Trucks	ATL Cars	ATL Trucks	Right Turn Cars	Right Turn Trucks	ATL Utilization (%)	% Right Turns	X_T	ATL Flow (vph)	Through Flow (vph)	Saturation Headway (pcphpl)	X_R
SB Garrett	336	879	7	41	0	12	0	16	0	23	23	0.32	49.1	217.1	2.00	0
SB Garrett	288	728	6	47	1	15	0	15	0	24	19	0.44	74.2	311.5	2.00	0
SB Garrett	336	918	7	48	0	18	0	25	0	27	27	0.39	70.6	258.8	2.00	0
SB Garrett	336	962	7	60	0	11	0	30	0	15	30	0.42	41.2	265.7	2.00	0
SB Garrett	336	901	7	45	0	15	0	22	0	25	27	0.36	59.9	239.7	2.00	0
NB MD 2	541	900	5	414	7	86	0	19	1	17	4	0.90	344.0	2028.0	1.92	0
NB MD 2	488	898	5	347	7	63	0	8	0	15	2	0.82	252.6	1671.7	1.93	0
NB MD 2	480	899	5	413	3	97	0	35	1	19	7	1.02	388.4	2054.3	1.91	0
NB MD 2	493	900	5	440	6	98	2	27	0	18	5	1.06	400.0	2184.0	1.92	0
NB MD 2	464	900	5	433	9	125	2	23	0	22	4	1.18	508.0	2276.0	1.93	0
NB MD 2	434	810	5	340	8	73	0	16	0	17	4	0.94	324.4	1871.1	1.93	0
NB MD 2	391	812	5	305	13	69	0	12	0	18	3	0.97	305.9	1715.8	1.96	0
NB MD 2	446	920	5	348	12	95	0	23	0	21	5	0.99	371.7	1780.4	1.94	0
NB MD 2	469	900	5	379	10	75	2	14	0	17	3	0.97	308.0	1864.0	1.94	0
NB MD 2	510	900	5	408	8	81	1	23	0	16	4	0.94	328.0	1992.0	1.93	0
NB MD 2	485	900	5	370	10	80	2	23	0	18	5	0.93	328.0	1848.0	1.94	0
NB MD 2	462	900	5	407	5	108	0	20	0	21	4	1.08	432.0	2080.0	1.91	0
NB MD 2	487	900	5	392	5	86	1	14	0	18	3	0.95	348.0	1936.0	1.92	0
NB MD 2	498	900	5	423	6	109	1	20	0	20	4	1.04	440.0	2156.0	1.92	0
NB MD 2	517	900	5	430	6	94	0	31	0	18	6	0.98	376.0	2120.0	1.92	0
NB MD 2	506	899	5	433	8	102	1	25	0	19	4	1.04	412.5	2178.4	1.93	0
NB MD 2	513	900	5	447	9	124	2	27	0	22	4	1.10	504.0	2328.0	1.93	0
NB MD 2	509	900	5	418	8	91	1	27	0	18	5	0.98	368.0	2072.0	1.93	0

Approach	(Max) effective green time (s)	Cycle Length (s)	# Cycles	CTL Cars	CTL Trucks	ATL Cars	ATL Trucks	Right Turn Cars	Right Turn Trucks	ATL Utilization (%)	% Right Turns	X_T	ATL Flow (vph)	Through Flow (vph)	Saturation Headway (pcphpl)	X_R
SB MD 2	437	756	5	359	7	72	1	2	0	20	0	0.81	347.6	1742.9	1.94	0
SB MD 2	413	750	5	343	11	93	0	2	0	26	0	0.84	446.4	1699.2	1.95	0
SB MD 2	412	749	5	351	15	114	1	5	0	31	1	0.88	552.7	1759.1	1.98	0
SB MD 2	417	749	5	326	10	86	3	4	0	26	1	0.79	427.8	1615.0	1.97	0
SB MD 2	435	749	5	307	7	61	0	4	0	19	1	0.70	293.2	1509.2	1.94	0
SB MD 2	457	802	5	326	8	75	0	6	0	22	1	0.71	336.7	1499.3	1.94	0
SB MD 2	470	839	5	309	12	72	1	8	0	23	2	0.67	313.2	1377.4	1.97	0
SB MD 2	391	749	5	311	2	48	1	12	0	16	3	0.77	235.5	1504.4	1.91	0
SB MD 2	453	909	5	294	5	46	1	7	0	16	2	0.64	186.1	1184.2	1.93	0
SB MD 2	471	890	5	290	7	55	2	5	1	19	2	0.62	230.6	1201.3	1.95	0
SB MD 2	407	749	5	227	3	38	1	7	0	17	3	0.54	187.4	1105.5	1.93	0
SB MD 2	378	749	5	248	3	31	1	3	1	13	1	0.64	153.8	1206.4	1.92	0
SB MD 2	437	820	5	262	5	35	0	5	0	13	2	0.59	153.7	1172.2	1.93	0
MD 214	550	895	6	388	18	9	0	15	0	2	3	0.75	36.2	1669.3	1.98	0
MD 214	605	900	6	420	23	18	0	26	0	4	5	0.76	72.0	1844.0	1.99	0
MD 214	568	900	6	418	11	19	0	24	1	4	5	0.77	76.0	1792.0	1.94	0
MD 214	591	900	6	462	9	12	0	28	0	2	5	0.79	48.0	1932.0	1.93	0
MD 214	594	900	6	500	12	27	1	27	1	5	5	0.88	112.0	2160.0	1.94	0
MD 214	562	900	6	518	8	29	1	23	0	5	4	0.95	120.0	2224.0	1.93	0
MD 214	591	900	6	535	9	23	0	17	0	4	3	0.92	92.0	2268.0	1.92	0
MD 214	590	900	6	579	4	39	1	28	0	6	4	1.01	160.0	2492.0	1.91	0
MD 214	533	900	6	514	5	39	0	25	0	7	4	1.00	156.0	2232.0	1.91	0
MD 214	541	900	6	511	5	37	0	38	0	7	6	0.98	148.0	2212.0	1.91	0
MD 214	534	899	6	530	3	47	0	41	0	8	7	1.03	188.2	2322.6	1.90	0
MD 214	521	900	6	513	2	38	0	55	0	7	9	1.01	152.0	2212.0	1.90	0

Approach	(Max) effective green time (s)	Cycle Length (s)	# Cycles	CTL Cars	CTL Trucks	ATL Cars	ATL Trucks	Right Turn Cars	Right Turn Trucks	ATL Utilization (%)	% Right Turns	X_T	ATL Flow (vph)	Through Flow (vph)	Saturation Headway (pcphpl)	X_R
NB IL 171 at IL 64	161	882	6	148	5	30	0	40	0	16	18	1.11	122.4	746.9	1.95	0.57
NB IL 171 at IL 64	169	960	6	135	4	20	0	31	1	13	17	0.91	75.0	596.3	1.94	0.43
NB IL 171 at IL 64	177	960	6	140	3	27	0	30	1	16	15	0.93	101.3	637.5	1.93	0.40
NB IL 171 at IL 64	164	960	6	131	5	25	0	29	1	16	16	0.96	93.8	603.8	1.95	0.42
NB IL 171 at IL 64	161	961	6	152	4	49	0	40	0	24	16	1.23	183.6	768.0	1.93	0.56
NB IL 171 at IL 64	177	960	6	150	6	36	1	32	2	19	15	1.07	138.8	723.8	1.96	0.44
NB IL 171 at IL 64	172	960	6	160	6	45	1	25	0	22	11	1.21	172.5	795.0	1.96	0.33
NB IL 171 at IL 64	162	960	6	163	5	37	0	49	0	18	19	1.23	138.8	768.8	1.94	0.69
NB IL 171 at IL 64	180	960	6	154	4	39	0	40	0	20	17	1.06	146.3	738.8	1.93	0.51
SB IL 171 at IL 64	222	882	6	147	13	25	0	92	2	14	34	0.84	102.0	755.1	2.03	1.01
SB IL 171 at IL 64	235	960	6	160	4	31	0	81	3	16	30	0.80	116.3	731.3	1.93	0.81
SB IL 171 at IL 64	240	961	6	162	4	38	0	79	3	19	29	0.82	142.4	764.2	1.93	0.78
SB IL 171 at IL 64	240	960	6	183	10	37	0	82	4	16	27	0.95	138.8	862.5	1.98	0.83
SB IL 171 at IL 64	240	960	6	172	10	35	1	89	0	17	29	0.90	135.0	817.5	1.99	0.87
SB IL 171 at IL 64	240	960	6	182	6	38	1	79	1	17	26	0.92	146.3	851.3	1.95	0.77
SB IL 171 at IL 64	240	960	6	207	10	65	0	63	3	23	19	1.15	243.8	1057.5	1.96	0.63
SB IL 171 at IL 64	240	960	6	193	4	40	3	67	1	18	22	0.98	161.3	900.0	1.95	0.65
SB IL 171 at IL 64	240	960	6	187	5	46	2	64	2	20	22	0.98	180.0	900.0	1.95	0.63

Approach	(Max) effective green time (s)	Cycle Length (s)	# Cycles	CTL Cars	CTL Trucks	ATL Cars	ATL Trucks	Right Turn Cars	Right Turn Trucks	ATL Utilization (%)	% Right Turns	X_T	ATL Flow (vph)	Through Flow (vph)	Saturation Headway (pcphpl)	X_R
NB IL 171 at Roosevelt	222	840	6	152	12	6	0	67	0	4	28	0.78	25.7	728.6	2.03	0.72
NB IL 171 at Roosevelt	222	840	6	171	11	8	0	60	0	4	24	0.86	34.3	814.3	2.00	0.64
NB IL 171 at Roosevelt	222	840	6	182	19	10	0	57	0	5	21	0.98	42.9	904.3	2.07	0.62
NB IL 171 at Roosevelt	188	841	6	146	11	8	2	71	0	6	30	0.91	42.8	714.9	2.04	0.91
NB IL 171 at Roosevelt	222	839	6	191	11	15	0	53	2	7	20	0.97	64.4	931.1	1.99	0.58
NB IL 171 at Roosevelt	222	840	6	194	9	10	0	59	0	5	22	0.95	42.9	912.9	1.97	0.62
NB IL 171 at Roosevelt	219	840	6	178	10	17	0	56	1	8	22	0.93	72.9	878.6	1.99	0.61
NB IL 171 at Roosevelt	222	840	6	191	6	12	0	53	0	6	20	0.92	51.4	895.7	1.95	0.55
NB IL 171 at Roosevelt	198	840	6	175	9	18	1	40	0	9	16	1.02	81.4	870.0	1.99	0.47
NB IL 171 at Roosevelt	228	829	6	192	10	18	0	43	1	8	17	0.96	78.2	955.4	1.98	0.45
SB IL 171 at Roosevelt	192	840	6	106	9	30	0	32	0	21	18	0.76	128.6	621.4	2.01	0
SB IL 171 at Roosevelt	177	841	6	137	10	58	0	25	1	28	11	1.15	248.3	877.5	1.99	0
SB IL 171 at Roosevelt	192	839	6	128	4	42	3	23	0	25	12	0.91	193.1	759.5	1.97	0
SB IL 171 at Roosevelt	192	840	6	132	9	49	3	33	0	27	15	1.01	222.9	827.1	2.01	0
SB IL 171 at Roosevelt	190	840	6	125	3	42	0	34	2	25	17	0.86	180.0	728.6	1.93	0
SB IL 171 at Roosevelt	192	840	6	131	9	43	1	21	0	24	10	0.96	188.6	788.6	2.00	0
SB IL 171 at Roosevelt	187	840	6	135	7	46	0	21	0	24	10	0.99	197.1	805.7	1.97	0
SB IL 171 at Roosevelt	228	934	7	181	5	58	1	22	0	24	8	1.04	227.4	944.3	1.94	0
SB IL 171 at Roosevelt	192	840	6	121	6	44	1	28	0	26	14	0.88	192.9	737.1	1.97	0
SB IL 171 at Roosevelt	192	840	6	126	7	58	0	15	2	30	8	0.98	248.6	818.6	1.96	0
Approach	(Max) effective	Cycle Length (s)	# Cycles	CTL Cars	CTL Trucks	ATL Cars	ATL Trucks	Right Turn	Right Turn	ATL Utilization	% Right Turns	X_T	ATL Flow	Through Flow	Saturation Headway	X_R

	green time (s)							Cars	Trucks	(%)			(vph)	(vph)	(pcphpl)	
US 1	615	875	5	357	15	65	0	35	0	15	7	0.70	267.4	1797.9	1.96	0
US 1	615	1007	5	373	18	66	0	61	0	14	12	0.77	235.9	1719.6	1.97	0
US 1	615	862	5	268	23	46	1	48	1	12	13	0.63	196.3	1612.1	2.01	0
US 1	615	941	5	225	11	41	0	58	0	12	17	0.53	156.9	1281.6	1.96	0
US 1	615	980	5	241	21	42	0	77	2	11	21	0.62	154.3	1399.6	2.00	0

TABLE B-2. Raw Data for Disaggregate Model

Site	Vehicle ID	ATL	CTL Queue	ATL Queue	Arrival after Red (s)	Green Time Remaining (s)	Queue Difference	g-hq
EB NC 54	1001	0	5	5	0	19	0	12
EB NC 54	1002	0	6	5	0	19	0	10
EB NC 54	1003	0	6	5	0	7	0	-2
EB NC 54	1004	0	7	4	0	21	0	11
EB NC 54	1005	1	8	4	0	20	0	8
EB NC 54	1006	0	0	0	0	7	0	11
EB NC 54	1007	0	0	0	0	11	0	21
EB NC 54	1008	1	3	0	0	16	0	20
EB NC 54	1009	0	3	1	0	13	0	16
EB NC 54	1010	0	5	2	0	18	0	14
EB NC 54	1011	0	4	1	0	20	0	16
EB NC 54	1012	1	0	0	0	15	0	19
EB NC 54	1013	0	0	0	0	11	0	15
EB NC 54	1014	0	5	1	0	17	0	10
EB NC 54	1015	0	6	1	0	13	0	4
EB NC 54	1016	0	0	0	0	15	0	19
EB NC 54	1017	0	1	0	0	13	0	15
EB NC 54	1018	1	2	0	0	21	0	22
EB NC 54	1019	0	0	0	0	17	0	22
EB NC 54	1020	0	7	3	0	23	0	12
EB NC 54	1021	1	5	3	0	24	0	16
EB NC 54	1022	0	3	2	0	20	0	17
EB NC 54	1023	0	4	2	0	17	0	12
EB NC 54	1024	1	4	2	0	22	0	16
EB NC 54	1025	1	4	3	0	13	0	7
EB NC 54	1026	0	0	0	0	17	0	24
EB NC 54	1027	0	1	0	0	12	0	17
EB NC 54	1028	0	1	0	0	10	0	15
EB NC 54	1029	0	5	0	0	19	0	15
EB NC 54	1030	0	6	0	0	13	0	7
EB NC 54	1031	1	4	3	0	24	0	18
EB NC 54	1032	0	4	4	0	21	0	15
EB NC 54	1033	0	5	4	0	19	0	11
EB NC 54	1034	0	0	0	0	9	0	10
EB NC 54	1035	1	8	2	0	18	0	3
EB NC 54	1036	0	0	0	0	10	0	12
EB NC 54	1037	0	9	2	0	16	0	0

EB NC 54	1038	0	10	2	0	9	0	-9
EB NC 54	1039	0	8	0	0	22	0	10
EB NC 54	1040	0	7	1	0	13	0	3
EB NC 54	1041	0	0	0	0	10	0	12
EB NC 54	1042	1	6	1	0	24	0	12
EB NC 54	1043	0	5	2	0	18	0	10
EB NC 54	1044	0	0	0	0	10	0	12
EB NC 54	1045	1	1	0	0	9	0	9
EB NC 54	1046	0	6	0	0	21	0	13
EB NC 54	1047	0	0	0	0	9	0	13
EB NC 54	1048	1	9	1	0	22	0	7
EB NC 54	1049	0	10	3	0	22	0	1
EB NC 54	1050	0	6	3	0	20	0	8
EB NC 54	1051	1	7	3	0	18	0	4
EB NC 54	1052	0	0	0	0	9	0	9
EB NC 54	1053	0	4	2	0	21	0	15
EB NC 54	1054	0	5	2	0	20	0	12
EB NC 54	1055	0	0	0	0	9	0	11
EB NC 54	1056	0	0	0	0	11	0	18
EB NC 54	1057	1	6	2	0	15	0	5
EB NC 54	1058	0	7	1	0	14	0	3
EB NC 54	1059	0	0	0	0	13	0	19
EB NC 54	1060	1	6	2	0	22	0	14
EB NC 54	1061	0	6	3	0	19	0	11
EB NC 54	1062	0	7	3	0	14	0	4
EB NC 54	1063	0	6	2	0	21	0	13
EB NC 54	1064	0	8	2	0	21	0	8
EB NC 54	1065	0	9	2	0	15	0	0
EB NC 54	1066	1	10	2	0	16	0	-3
EB NC 54	1067	0	9	4	0	20	0	6
EB NC 54	1068	0	0	0	4	0	0	26
EB NC 54	1069	0	1	0	12	0	1	24
EB NC 54	1070	1	2	0	13	0	2	22
EB NC 54	1071	1	2	1	17	0	1	22
EB NC 54	1072	0	2	2	19	0	0	22
EB NC 54	1073	0	3	2	42	0	1	20
EB NC 54	1074	0	4	2	49	0	2	18
EB NC 54	1075	1	5	2	63	0	3	16
EB NC 54	1076	1	5	3	67	0	2	16
EB NC 54	1077	1	5	4	77	0	1	16

EB NC 54	1078	0	1	0	-4	0	1	24
EB NC 54	1079	1	2	0	31	0	2	22
EB NC 54	1080	0	2	1	37	0	1	22
EB NC 54	1081	0	3	1	76	0	2	20
EB NC 54	1082	0	0	0	-5	0	0	26
EB NC 54	1083	0	1	0	-1	0	1	24
EB NC 54	1084	0	2	0	5	0	2	22
EB NC 54	1085	0	3	0	14	0	3	20
EB NC 54	1086	1	4	0	16	0	4	18
EB NC 54	1087	0	4	1	30	0	3	18
EB NC 54	1088	1	5	1	56	0	4	16
EB NC 54	1089	1	5	2	58	0	3	16
EB NC 54	1090	0	5	3	59	0	2	16
EB NC 54	1091	0	6	3	70	0	3	14
EB NC 54	1092	1	7	3	63	0	4	12
EB NC 54	1093	1	0	0	-3	0	0	26
EB NC 54	1094	0	0	1	40	0	-1	26
EB NC 54	1095	0	1	1	60	0	0	24
EB NC 54	1096	0	0	0	76	0	0	26
EB NC 54	1097	0	1	0	28	0	1	24
EB NC 54	1098	0	2	0	39	0	2	22
EB NC 54	1099	0	3	0	60	0	3	20
EB NC 54	1100	1	4	0	65	0	4	18
EB NC 54	1101	0	0	0	0	0	0	26
EB NC 54	1102	0	1	0	43	0	1	24
EB NC 54	1103	0	2	0	48	0	2	22
EB NC 54	1104	0	0	0	10	0	0	26
EB NC 54	1105	1	1	0	60	0	1	24
EB NC 54	1106	0	1	1	71	0	0	24
EB NC 54	1107	0	0	0	40	0	0	26
EB NC 54	1108	0	1	0	48	0	1	24
EB NC 54	1109	0	2	0	51	0	2	22
EB NC 54	1110	1	0	0	3	0	0	26
EB NC 54	1111	0	0	1	16	0	-1	26
EB NC 54	1112	1	1	1	31	0	0	24
EB NC 54	1113	0	1	2	38	0	-1	24
EB NC 54	1114	0	2	2	70	0	0	22
EB NC 54	1115	0	3	2	77	0	1	20
EB NC 54	1116	1	0	0	-9	0	0	26
EB NC 54	1117	0	0	1	66	0	-1	26

EB NC 54	1118	0	1	1	69	0	0	24
EB NC 54	1119	0	2	1	71	0	1	22
EB NC 54	1120	0	3	1	73	0	2	20
EB NC 54	1121	1	4	1	73	0	3	18
EB NC 54	1122	0	4	2	77	0	2	18
EB NC 54	1123	0	0	0	41	0	0	26
EB NC 54	1124	0	1	0	53	0	1	24
EB NC 54	1125	0	2	0	58	0	2	22
EB NC 54	1126	0	3	0	71	0	3	20
EB NC 54	1127	0	4	0	74	0	4	18
EB NC 54	1128	1	0	0	18	0	0	26
EB NC 54	1129	0	0	1	27	0	-1	26
EB NC 54	1130	0	1	1	29	0	0	24
EB NC 54	1131	0	2	1	35	0	1	22
EB NC 54	1132	0	3	1	52	0	2	20
EB NC 54	1133	0	4	1	59	0	3	18
EB NC 54	1134	0	0	0	-4	0	0	26
EB NC 54	1135	1	1	0	19	0	1	24
EB NC 54	1136	0	1	1	21	0	0	24
EB NC 54	1137	0	2	1	33	0	1	22
EB NC 54	1138	0	3	1	38	0	2	20
EB NC 54	1139	0	0	0	1	0	0	26
EB NC 54	1140	0	1	0	15	0	1	24
EB NC 54	1141	0	2	0	39	0	2	22
EB NC 54	1142	1	3	0	43	0	3	20
EB NC 54	1143	0	3	1	47	0	2	20
EB NC 54	1144	0	4	1	49	0	3	18
EB NC 54	1145	0	5	1	75	0	4	16
EB NC 54	1146	0	0	0	1	0	0	26
EB NC 54	1147	1	1	0	32	0	1	24
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EB NC 54	1149	0	2	1	55	0	1	22
EB NC 54	1150	0	3	1	56	0	2	20
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EB NC 54	1152	1	0	0	76	0	0	26
EB NC 54	1153	0	0	0	46	0	0	26
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EB NC 54	1155	0	0	0	0	0	0	26
EB NC 54	1156	0	1	0	3	0	1	24
EB NC 54	1157	1	2	0	9	0	2	22

EB NC 54	1158	0	2	1	16	0	1	22
EB NC 54	1159	0	3	1	37	0	2	20
EB NC 54	1160	0	4	1	42	0	3	18
EB NC 54	1161	1	5	1	42	0	4	16
EB NC 54	1162	0	5	2	44	0	3	16
EB NC 54	1163	0	6	2	48	0	4	14
EB NC 54	1164	1	7	2	57	0	5	12
EB NC 54	1165	0	0	0	-9	0	0	26
EB NC 54	1166	1	1	0	16	0	1	24
EB NC 54	1167	1	1	1	20	0	0	24
EB NC 54	1168	0	1	2	23	0	-1	24
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EB NC 54	1173	0	2	0	15	0	2	22
EB NC 54	1174	1	3	0	34	0	3	20
EB NC 54	1175	0	3	1	32	0	2	20
EB NC 54	1176	1	3	2	52	0	1	20
EB NC 54	1177	0	3	3	56	0	0	20
EB NC 54	1178	0	4	3	63	0	1	18
EB NC 54	1179	0	0	0	-10	0	0	26
EB NC 54	1180	0	1	0	-9	0	1	24
EB NC 54	1181	0	2	0	4	0	2	22
EB NC 54	1182	0	3	0	12	0	3	20
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EB NC 54	1184	1	2	0	0	0	2	22
EB NC 54	1185	0	0	0	24	0	0	26
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EB NC 54	1189	0	0	1	1	0	-1	26
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EB NC 54	1192	0	2	2	21	0	0	22
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EB NC 54	1194	0	0	1	20	0	-1	26
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EB NC 54	1197	1	3	1	61	0	2	20

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EB NC 54	1217	0	3	1	17	0	2	20
EB NC 54	1218	0	4	0	64	0	4	18
EB NC 54	1219	0	0	0	-5	0	0	26
EB NC 54	1220	0	1	0	0	0	1	24
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EB NC 54	1222	0	3	0	16	0	3	20
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EB NC 54	1224	1	5	0	17	0	5	16
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EB NC 54	1227	0	7	1	24	0	6	12
EB NC 54	1228	0	8	1	29	0	7	10
EB NC 54	1229	0	9	1	51	0	8	8
EB NC 54	1230	1	10	1	53	0	9	6
EB NC 54	1231	1	0	0	2	0	0	26
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EB NC 54	1235	0	2	2	63	0	0	22
EB NC 54	1236	0	3	2	65	0	1	20
EB NC 54	1237	1	4	2	67	0	2	18

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EB NC 54	1241	0	3	0	31	0	3	20
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EB NC 54	1243	0	4	1	58	0	3	18
EB NC 54	1244	1	0	0	-1	0	0	26
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EB NC 54	1250	0	4	2	70	0	2	18
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EB NC 54	1255	0	7	4	111	0	3	12
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EB NC 54	1275	0	4	2	67	0	2	18
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EB NC 54	1280	0	1	1	27	0	0	24
EB NC 54	1281	1	2	1	33	0	1	22
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EB NC 54	1291	0	3	0	30	0	3	20
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EB NC 54	1293	0	5	0	36	0	5	16
EB NC 54	1294	0	6	0	64	0	6	14
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EB NC 54	1301	0	4	1	45	0	3	18
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EB NC 54	1321	0	3	0	10	0	3	20
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EB NC 54	1323	1	5	0	48	0	5	16
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EB NC 54	1339	1	3	1	33	0	2	20
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EB NC 54	1367	0	10	2	81	0	8	6
EB NC 54	1368	1	11	2	84	0	9	4
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EB NC 54	1380	1	4	1	21	0	3	18
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EB NC 54	1419	0	4	0	40	0	4	18
EB NC 54	1420	0	5	0	42	0	5	16
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EB NC 54	1468	0	2	1	0	0	1	22
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EB NC 54	1475	0	7	3	53	0	4	12
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EB NC 54	1479	1	1	0	21	0	1	24
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EB NC 54	1481	0	2	1	55	0	1	22
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EB NC 54	1495	0	7	4	47	0	3	12
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NB Garrett	2001	0	5	2	0	26	0	32
NB Garrett	2002	0	6	2	0	21	0	25
NB Garrett	2003	1	7	2	0	18	0	20
NB Garrett	2004	0	5	1	0	20	0	37
NB Garrett	2005	1	6	1	0	18	0	33
NB Garrett	2006	0	6	2	0	5	0	20
NB Garrett	2007	0	7	2	0	4	0	17
NB Garrett	2008	0	9	4	0	25	0	23
NB Garrett	2009	0	10	4	0	14	0	10
NB Garrett	2010	0	6	3	0	29	0	26
NB Garrett	2011	0	7	3	0	26	0	21
NB Garrett	2012	0	8	3	0	18	0	11
NB Garrett	2013	0	9	3	0	14	0	5
NB Garrett	2014	0	10	3	0	13	0	2
NB Garrett	2015	0	11	3	0	11	0	-2
NB Garrett	2016	1	5	1	0	41	0	37
NB Garrett	2017	0	5	2	0	31	0	27
NB Garrett	2018	0	6	2	0	24	0	18
NB Garrett	2019	0	7	2	0	22	0	14
NB Garrett	2020	0	8	2	0	16	0	6
NB Garrett	2021	1	9	2	0	11	0	-1

NB Garrett	2022	1	8	3	0	28	0	21
NB Garrett	2023	0	8	4	0	21	0	14
NB Garrett	2024	0	9	4	0	19	0	10
NB Garrett	2025	0	10	4	0	18	0	7
NB Garrett	2026	0	11	4	0	17	0	4
NB Garrett	2027	0	12	4	0	15	0	0
NB Garrett	2028	0	13	4	0	5	0	-12
NB Garrett	2029	0	5	2	0	16	0	30
NB Garrett	2030	0	5	2	0	14	0	21
NB Garrett	2031	1	11	2	0	35	0	24
NB Garrett	2032	1	11	3	0	17	0	6
NB Garrett	2033	0	11	4	0	12	0	1
NB Garrett	2034	0	4	2	0	23	0	34
NB Garrett	2035	0	5	2	0	21	0	30
NB Garrett	2036	0	6	2	0	18	0	25
NB Garrett	2037	0	7	2	0	17	0	22
NB Garrett	2038	0	6	2	0	13	0	23
NB Garrett	2039	0	3	2	0	20	0	38
NB Garrett	2040	0	5	2	0	35	0	36
NB Garrett	2041	0	6	2	0	31	0	30
NB Garrett	2042	0	7	2	0	17	0	14
NB Garrett	2043	0	5	2	0	16	0	28
NB Garrett	2044	0	5	3	0	12	0	24
NB Garrett	2045	0	1	0	0	24	0	41
NB Garrett	2046	0	2	0	0	16	0	31
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NB Garrett	2051	1	10	2	0	24	0	14
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NB Garrett	2053	0	0	0	0	22	0	27
NB Garrett	2054	0	0	0	0	14	0	19
NB Garrett	2055	1	9	3	0	34	0	24
NB Garrett	2056	0	9	4	0	31	0	21
NB Garrett	2057	1	10	4	0	30	0	18
NB Garrett	2058	0	10	5	0	29	0	17
NB Garrett	2059	0	0	0	0	7	0	23
NB Garrett	2060	0	1	0	0	3	0	17
NB Garrett	2061	0	0	0	0	13	0	24

NB Garrett	2062	1	4	0	0	25	0	34
NB Garrett	2063	0	0	0	0	16	0	33
NB Garrett	2064	0	1	0	0	14	0	29
NB Garrett	2065	0	0	0	0	12	0	29
NB Garrett	2066	0	5	0	0	22	0	36
NB Garrett	2067	0	6	0	0	16	0	28
NB Garrett	2068	0	7	0	0	8	0	18
NB Garrett	2069	0	6	2	0	22	0	31
NB Garrett	2070	0	0	0	0	8	0	29
NB Garrett	2071	0	7	4	0	20	0	26
NB Garrett	2072	0	8	4	0	8	0	12
NB Garrett	2073	0	3	1	0	23	0	39
NB Garrett	2074	0	0	0	0	16	0	38
NB Garrett	2075	0	7	2	0	17	0	28
NB Garrett	2076	0	0	0	16	0	0	48
NB Garrett	2077	0	1	0	44	0	1	46
NB Garrett	2078	0	2	0	46	0	2	44
NB Garrett	2079	0	3	0	48	0	3	42
NB Garrett	2080	1	3	0	66	0	3	42
NB Garrett	2081	1	3	1	77	0	2	42
NB Garrett	2082	0	3	2	82	0	1	42
NB Garrett	2083	0	4	2	84	0	2	40
NB Garrett	2084	0	0	0	6	0	0	48
NB Garrett	2085	0	1	0	15	0	1	46
NB Garrett	2086	0	2	0	25	0	2	44
NB Garrett	2087	1	3	0	52	0	3	42
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NB Garrett	2089	0	4	1	68	0	3	40
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NB Garrett	2091	0	2	1	17	0	1	44
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NB Garrett	2096	0	5	3	41	0	2	38
NB Garrett	2097	0	6	3	61	0	3	36
NB Garrett	2098	1	7	3	64	0	4	34
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NB Garrett	2100	0	8	4	87	0	4	32
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NB Garrett	2103	1	2	0	11	0	2	44
NB Garrett	2104	0	2	1	18	0	1	44
NB Garrett	2105	0	3	1	25	0	2	42
NB Garrett	2106	0	4	1	45	0	3	40
NB Garrett	2107	1	5	1	52	0	4	38
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NB Garrett	2109	1	6	2	81	0	4	36
NB Garrett	2110	0	0	0	6	0	0	48
NB Garrett	2111	0	1	0	32	0	1	46
NB Garrett	2112	0	2	0	56	0	2	44
NB Garrett	2113	0	3	0	75	0	3	42
NB Garrett	2114	0	4	0	78	0	4	40
NB Garrett	2115	1	5	0	89	0	5	38
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NB Garrett	2123	1	6	1	70	0	5	36
NB Garrett	2124	0	6	2	86	0	4	36
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NB Garrett	2127	0	0	0	9	0	0	48
NB Garrett	2128	1	1	0	14	0	1	46
NB Garrett	2129	0	1	1	36	0	0	46
NB Garrett	2130	0	0	0	0	0	0	48
NB Garrett	2131	0	1	0	16	0	1	46
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NB Garrett	2135	0	3	2	69	0	1	42
NB Garrett	2136	0	4	2	72	0	2	40
NB Garrett	2137	0	0	0	14	0	0	48
NB Garrett	2138	0	1	0	18	0	1	46
NB Garrett	2139	0	2	0	31	0	2	44
NB Garrett	2140	0	3	0	49	0	3	42
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NB Garrett	2142	1	5	0	69	0	5	38
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NB Garrett	2144	1	1	0	17	0	1	46
NB Garrett	2145	1	1	1	28	0	0	46
NB Garrett	2146	0	1	2	33	0	-1	46
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NB Garrett	2149	0	4	2	61	0	2	40
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NB Garrett	2153	0	3	0	26	0	3	42
NB Garrett	2154	0	4	0	36	0	4	40
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NB Garrett	2163	0	0	0	3	0	0	48
NB Garrett	2164	1	1	0	4	0	1	46
NB Garrett	2165	0	1	1	9	0	0	46
NB Garrett	2166	0	2	1	13	0	1	44
NB Garrett	2167	1	3	1	15	0	2	42
NB Garrett	2168	0	3	2	31	0	1	42
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NB Garrett	2176	1	6	1	93	0	5	36
NB Garrett	2177	0	0	0	25	0	0	48
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NB Garrett	2179	1	2	0	53	0	2	44
NB Garrett	2180	1	2	1	60	0	1	44
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NB Garrett	2182	0	0	0	47	0	0	48
NB Garrett	2183	0	1	0	60	0	1	46
NB Garrett	2184	0	2	0	66	0	2	44
NB Garrett	2185	1	3	0	70	0	3	42
NB Garrett	2186	1	3	1	75	0	2	42
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NB Garrett	2188	0	4	2	83	0	2	40
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NB Garrett	2192	0	2	1	53	0	1	44
NB Garrett	2193	0	3	1	62	0	2	42
NB Garrett	2194	0	4	1	67	0	3	40
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NB Garrett	2196	0	0	0	23	0	0	48
NB Garrett	2197	0	0	0	0	0	0	48
NB Garrett	2198	0	1	0	33	0	1	46
NB Garrett	2199	0	2	0	51	0	2	44
NB Garrett	2200	0	3	1	53	0	2	42
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NB Garrett	2202	0	5	1	81	0	4	38
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NB Garrett	2211	0	5	1	41	0	4	38
NB Garrett	2212	0	6	1	64	0	5	36
NB Garrett	2213	0	7	1	69	0	6	34
NB Garrett	2214	0	8	1	85	0	7	32
NB Garrett	2215	0	9	1	87	0	8	30
NB Garrett	2216	0	0	0	14	0	0	48
NB Garrett	2217	1	0	0	-2	0	0	48
NB Garrett	2218	0	0	1	21	0	-1	48
NB Garrett	2219	1	1	1	22	0	0	46
NB Garrett	2220	0	1	2	31	0	-1	46
NB Garrett	2221	0	2	2	41	0	0	44

NB Garrett	2222	0	3	2	48	0	1	42
NB Garrett	2223	0	4	2	52	0	2	40
NB Garrett	2224	0	5	2	55	0	3	38
NB Garrett	2225	1	6	2	62	0	4	36
NB Garrett	2226	0	6	3	70	0	3	36
NB Garrett	2227	0	7	3	74	0	4	34
NB Garrett	2228	0	8	3	103	0	5	32
NB Garrett	2229	0	0	0	4	0	0	48
NB Garrett	2230	0	1	0	30	0	1	46
NB Garrett	2231	0	2	1	51	0	1	44
NB Garrett	2232	0	0	0	3	0	0	48
NB Garrett	2233	0	1	0	13	0	1	46
NB Garrett	2234	0	2	0	26	0	2	44
NB Garrett	2235	0	3	0	35	0	3	42
NB Garrett	2236	0	4	0	37	0	4	40
NB Garrett	2237	0	5	0	39	0	5	38
NB Garrett	2238	0	6	0	43	0	6	36
NB Garrett	2239	0	7	0	63	0	7	34
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NB Garrett	2247	0	1	0	4	0	1	46
NB Garrett	2248	1	2	0	36	0	2	44
NB Garrett	2249	0	2	1	39	0	1	44
NB Garrett	2250	0	0	0	73	0	0	48
NB Garrett	2251	0	0	0	8	0	0	48
NB Garrett	2252	0	1	0	57	0	1	46
NB Garrett	2253	0	2	0	64	0	2	44
NB Garrett	2254	0	3	0	82	0	3	42
NB Garrett	2255	0	0	0	8	0	0	48
NB Garrett	2256	0	1	0	26	0	1	46
NB Garrett	2257	0	2	0	45	0	2	44
NB Garrett	2258	0	3	0	48	0	3	42
NB Garrett	2259	0	4	0	99	0	4	40
NB Garrett	2260	0	0	0	16	0	0	48
NB Garrett	2261	0	1	0	24	0	1	46

NB Garrett	2262	0	2	0	30	0	2	44
NB Garrett	2263	0	3	0	34	0	3	42
NB Garrett	2264	1	4	0	47	0	4	40
NB Garrett	2265	0	4	1	55	0	3	40
NB Garrett	2266	0	5	1	65	0	4	38
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NB Garrett	2268	0	0	0	-5	0	0	48
NB Garrett	2269	0	1	0	-3	0	1	46
NB Garrett	2270	0	2	0	2	0	2	44
NB Garrett	2271	0	3	0	4	0	3	42
NB Garrett	2272	0	4	0	52	0	4	40
NB Garrett	2273	1	5	0	55	0	5	38
NB Garrett	2274	0	5	1	62	0	4	38
NB Garrett	2275	1	6	1	74	0	5	36
NB Garrett	2276	0	0	1	32	0	-1	48
NB Garrett	2277	0	1	1	34	0	0	46
NB Garrett	2278	0	2	1	37	0	1	44
NB Garrett	2279	0	3	1	45	0	2	42
NB Garrett	2280	0	4	1	47	0	3	40
NB Garrett	2281	0	5	1	54	0	4	38
NB Garrett	2282	0	6	1	49	0	5	36
NB Garrett	2283	0	7	1	66	0	6	34
NB Garrett	2284	0	8	1	70	0	7	32
NB Garrett	2285	0	9	1	72	0	8	30
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NB Garrett	2287	0	1	0	22	0	1	46
NB Garrett	2288	0	2	0	25	0	2	44
NB Garrett	2289	1	3	0	30	0	3	42
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NB Garrett	2291	0	4	1	48	0	3	40
NB Garrett	2292	0	5	1	53	0	4	38
NB Garrett	2293	1	6	1	54	0	5	36
NB Garrett	2294	1	6	2	64	0	4	36
NB Garrett	2295	1	6	3	89	0	3	36
NB Garrett	2296	0	6	4	93	0	2	36
NB Garrett	2297	0	0	0	1	0	0	48
NB Garrett	2298	0	1	0	49	0	1	46
NB Garrett	2299	1	2	0	67	0	2	44
NB Garrett	2300	0	2	1	74	0	1	44
NB Garrett	2301	0	0	0	29	0	0	48

NB Garrett	2302	1	1	0	29	0	1	46
NB Garrett	2303	0	1	2	67	0	-1	46
NB Garrett	2304	0	0	0	-4	0	0	48
NB Garrett	2305	0	1	0	4	0	1	46
NB Garrett	2306	1	2	0	11	0	2	44
NB Garrett	2307	0	2	1	33	0	1	44
NB Garrett	2308	0	3	1	49	0	2	42
NB Garrett	2309	0	4	1	56	0	3	40
NB Garrett	2310	0	5	1	60	0	4	38
NB Garrett	2311	1	6	1	66	0	5	36
SB Garrett	3001	0	3	1	0	13	0	21
SB Garrett	3002	0	4	1	0	6	0	12
SB Garrett	3003	0	0	0	0	10	0	34
SB Garrett	3004	0	3	0	0	20	0	27
SB Garrett	3005	0	4	0	0	18	0	23
SB Garrett	3006	0	5	0	0	17	0	20
SB Garrett	3007	1	6	0	0	16	0	17
SB Garrett	3008	1	6	1	0	13	0	14
SB Garrett	3009	0	6	2	0	11	0	12
SB Garrett	3010	1	1	0	0	4	0	20
SB Garrett	3011	0	0	0	0	19	0	42
SB Garrett	3012	1	9	5	0	21	0	27
SB Garrett	3013	0	2	1	0	29	0	41
SB Garrett	3014	0	3	1	0	27	0	37
SB Garrett	3015	0	4	1	0	21	0	29
SB Garrett	3016	0	0	0	0	15	0	31
SB Garrett	3017	0	7	0	0	20	0	21
SB Garrett	3018	0	8	0	0	19	0	18
SB Garrett	3019	1	0	0	0	15	0	30
SB Garrett	3020	0	0	1	0	14	0	29
SB Garrett	3021	0	0	0	0	5	0	28
SB Garrett	3022	1	9	3	0	33	0	24
SB Garrett	3023	0	9	4	0	22	0	13
SB Garrett	3024	0	0	0	0	16	0	27
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SB Garrett	3027	0	0	0	0	20	0	21
SB Garrett	3028	1	0	0	0	6	0	7
SB Garrett	3029	0	0	0	0	7	0	27
SB Garrett	3030	0	1	0	0	6	0	24

SB Garrett	3031	0	6	1	0	24	0	34
SB Garrett	3032	0	8	2	0	21	0	21
SB Garrett	3033	0	9	2	0	17	0	15
SB Garrett	3034	0	10	2	0	14	0	10
SB Garrett	3035	0	0	0	0	6	0	22
SB Garrett	3036	0	0	0	0	34	0	32
SB Garrett	3037	0	0	0	0	20	0	18
SB Garrett	3038	1	0	0	0	10	0	8
SB Garrett	3039	0	0	1	0	5	0	3
SB Garrett	3040	0	5	2	0	45	0	36
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SB Garrett	3042	0	0	0	0	24	0	40
SB Garrett	3043	0	0	0	0	22	0	38
SB Garrett	3044	0	0	0	0	5	0	29
SB Garrett	3045	0	0	0	0	43	0	41
SB Garrett	3046	0	0	0	0	41	0	39
SB Garrett	3047	0	0	0	0	37	0	35
SB Garrett	3048	0	0	0	0	27	0	25
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SB Garrett	3050	0	8	2	0	18	0	12
SB Garrett	3051	0	9	2	0	16	0	8
SB Garrett	3052	0	10	2	0	12	0	2
SB Garrett	3053	1	11	2	0	11	0	-1
SB Garrett	3054	0	6	1	0	24	0	31
SB Garrett	3055	0	7	1	0	23	0	28
SB Garrett	3056	0	8	1	0	21	0	24
SB Garrett	3057	0	0	0	14	0	0	48
SB Garrett	3058	1	1	0	48	0	1	46
SB Garrett	3059	0	1	1	64	0	0	46
SB Garrett	3060	0	2	1	68	0	1	44
SB Garrett	3061	0	0	0	-3	0	0	48
SB Garrett	3062	0	1	0	55	0	1	46
SB Garrett	3063	0	2	0	64	0	2	44
SB Garrett	3064	0	3	0	73	0	3	42
SB Garrett	3065	1	4	0	73	0	4	40
SB Garrett	3066	0	0	0	49	0	0	48
SB Garrett	3067	0	1	0	53	0	1	46
SB Garrett	3068	0	2	0	57	0	2	44
SB Garrett	3069	1	3	0	58	0	3	42
SB Garrett	3070	0	0	0	12	0	0	48

SB Garrett	3071	0	1	0	25	0	1	46
SB Garrett	3072	0	2	0	42	0	2	44
SB Garrett	3073	0	0	0	0	0	0	48
SB Garrett	3074	1	1	0	18	0	1	46
SB Garrett	3075	1	1	1	26	0	0	46
SB Garrett	3076	0	1	2	34	0	-1	46
SB Garrett	3077	0	2	2	52	0	0	44
SB Garrett	3078	0	3	2	69	0	1	42
SB Garrett	3079	0	1	0	12	0	1	46
SB Garrett	3080	0	2	0	14	0	2	44
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SB Garrett	3082	1	3	1	30	0	2	42
SB Garrett	3083	0	3	2	33	0	1	42
SB Garrett	3084	0	4	2	39	0	2	40
SB Garrett	3085	0	5	2	43	0	3	38
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SB Garrett	3087	1	7	2	89	0	5	34
SB Garrett	3088	0	7	3	94	0	4	34
SB Garrett	3089	0	8	3	96	0	5	32
SB Garrett	3090	0	9	3	98	0	6	30
SB Garrett	3091	0	10	3	100	0	7	28
SB Garrett	3092	0	0	0	-4	0	0	48
SB Garrett	3093	0	1	0	40	0	1	46
SB Garrett	3094	1	2	0	45	0	2	44
SB Garrett	3095	0	2	1	60	0	1	44
SB Garrett	3096	0	3	1	81	0	2	42
SB Garrett	3097	0	0	0	11	0	0	48
SB Garrett	3098	0	1	0	19	0	1	46
SB Garrett	3099	0	2	0	21	0	2	44
SB Garrett	3100	1	3	0	22	0	3	42
SB Garrett	3101	1	3	1	39	0	2	42
SB Garrett	3102	1	3	2	42	0	1	42
SB Garrett	3103	0	3	3	44	0	0	42
SB Garrett	3104	0	4	3	46	0	1	40
SB Garrett	3105	0	5	3	51	0	2	38
SB Garrett	3106	0	6	3	53	0	3	36
SB Garrett	3107	1	7	3	56	0	4	34
SB Garrett	3108	0	7	4	57	0	3	34
SB Garrett	3109	0	8	4	59	0	4	32
SB Garrett	3110	1	9	4	82	0	5	30

SB Garrett	3111	0	0	0	51	0	0	48
SB Garrett	3112	0	1	0	68	0	1	46
SB Garrett	3113	1	2	0	87	0	2	44
SB Garrett	3114	0	0	0	33	0	0	48
SB Garrett	3115	0	1	0	38	0	1	46
SB Garrett	3116	0	2	0	70	0	2	44
SB Garrett	3117	0	3	0	72	0	3	42
SB Garrett	3118	0	4	0	74	0	4	40
SB Garrett	3119	0	5	0	79	0	5	38
SB Garrett	3120	0	6	0	83	0	6	36
SB Garrett	3121	0	0	0	6	0	0	48
SB Garrett	3122	0	1	0	17	0	1	46
SB Garrett	3123	0	2	0	26	0	2	44
SB Garrett	3124	0	3	0	29	0	3	42
SB Garrett	3125	0	4	0	31	0	4	40
SB Garrett	3126	0	5	0	34	0	5	38
SB Garrett	3127	1	6	0	40	0	6	36
SB Garrett	3128	1	6	1	44	0	5	36
SB Garrett	3129	0	0	0	0	0	0	48
SB Garrett	3130	1	1	0	2	0	1	46
SB Garrett	3131	0	1	1	3	0	0	46
SB Garrett	3132	0	2	1	6	0	1	44
SB Garrett	3133	0	3	1	8	0	2	42
SB Garrett	3134	0	4	1	11	0	3	40
SB Garrett	3135	0	5	1	14	0	4	38
SB Garrett	3136	0	6	1	17	0	5	36
SB Garrett	3137	1	7	1	53	0	6	34
SB Garrett	3138	1	7	2	67	0	5	34
SB Garrett	3139	0	7	3	74	0	4	34
SB Garrett	3140	0	8	3	76	0	5	32
SB Garrett	3141	0	0	0	0	0	0	48
SB Garrett	3142	0	1	0	16	0	1	46
SB Garrett	3143	0	2	0	20	0	2	44
SB Garrett	3144	0	3	0	47	0	3	42
SB Garrett	3145	0	4	0	56	0	4	40
SB Garrett	3146	0	5	0	68	0	5	38
SB Garrett	3147	0	6	0	74	0	6	36
SB Garrett	3148	0	0	1	-3	0	-1	48
SB Garrett	3149	0	1	1	25	0	0	46
SB Garrett	3150	1	2	1	33	0	1	44

SB Garrett	3151	0	2	2	36	0	0	44
SB Garrett	3152	0	3	2	56	0	1	42
SB Garrett	3153	0	4	2	57	0	2	40
SB Garrett	3154	1	5	2	58	0	3	38
SB Garrett	3155	0	5	3	65	0	2	38
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SB Garrett	3159	1	2	1	28	0	1	44
SB Garrett	3160	0	2	2	44	0	0	44
SB Garrett	3161	0	3	2	69	0	1	42
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SB Garrett	3163	0	5	2	85	0	3	38
SB Garrett	3164	0	1	0	38	0	1	46
SB Garrett	3165	0	2	0	41	0	2	44
SB Garrett	3166	0	3	0	67	0	3	42
SB Garrett	3167	1	4	0	73	0	4	40
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SB Garrett	3169	0	5	1	77	0	4	38
SB Garrett	3170	0	0	0	22	0	0	48
SB Garrett	3171	0	1	0	25	0	1	46
SB Garrett	3172	0	2	0	34	0	2	44
SB Garrett	3173	0	3	0	36	0	3	42
SB Garrett	3174	1	4	0	78	0	4	40
SB Garrett	3175	0	4	1	82	0	3	40
SB Garrett	3176	0	5	1	87	0	4	38
SB Garrett	3177	0	6	1	92	0	5	36
SB Garrett	3178	0	0	0	1	0	0	48
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SB Garrett	3182	1	2	2	23	0	0	44
SB Garrett	3183	0	2	3	26	0	-1	44
SB Garrett	3184	0	3	3	29	0	0	42
SB Garrett	3185	1	4	3	32	0	1	40
SB Garrett	3186	0	3	5	32	0	-2	42
SB Garrett	3187	0	0	0	26	0	0	48
SB Garrett	3188	1	1	0	30	0	1	46
SB Garrett	3189	0	1	1	32	0	0	46
SB Garrett	3190	0	2	1	39	0	1	44

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SB Garrett	3192	0	4	1	65	0	3	40
SB Garrett	3193	0	5	1	67	0	4	38
SB Garrett	3194	1	6	1	73	0	5	36
SB Garrett	3195	0	6	2	75	0	4	36
SB Garrett	3196	0	7	2	77	0	5	34
SB Garrett	3197	1	0	0	2	0	0	48
SB Garrett	3198	0	0	1	3	0	-1	48
SB Garrett	3199	0	1	1	6	0	0	46
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SB Garrett	3201	0	3	1	22	0	2	42
SB Garrett	3202	1	4	1	43	0	3	40
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SB Garrett	3205	1	6	2	82	0	4	36
SB Garrett	3206	0	6	3	90	0	3	36
SB Garrett	3207	0	7	3	92	0	4	34
SB Garrett	3208	0	8	3	94	0	5	32
SB Garrett	3209	0	9	3	96	0	6	30
SB Garrett	3210	0	10	3	98	0	7	28
SB Garrett	3211	0	0	0	-3	0	0	48
SB Garrett	3212	1	1	0	11	0	1	46
SB Garrett	3213	0	1	1	22	0	0	46
SB Garrett	3214	0	2	1	24	0	1	44
SB Garrett	3215	0	3	1	28	0	2	42
SB Garrett	3216	0	0	0	0	0	0	48
SB Garrett	3217	0	1	0	2	0	1	46
SB Garrett	3218	0	2	0	39	0	2	44
SB Garrett	3219	0	3	0	64	0	3	42
SB Garrett	3220	1	4	0	80	0	4	40
SB Garrett	3221	0	4	1	88	0	3	40
SB Garrett	3222	1	5	1	88	0	4	38
SB Garrett	3223	0	0	0	-1	0	0	48
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SB Garrett	3227	1	3	1	25	0	2	42
SB Garrett	3228	0	3	2	77	0	1	42
SB Garrett	3229	0	4	2	80	0	2	40
SB Garrett	3230	0	0	0	20	0	0	48

SB Garrett	3231	0	1	0	43	0	1	46
SB Garrett	3232	0	2	0	55	0	2	44
SB Garrett	3233	0	3	0	64	0	3	42
SB Garrett	3234	0	4	0	69	0	4	40
SB Garrett	3235	0	5	0	72	0	5	38
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SB Garrett	3237	1	6	1	77	0	5	36
SB Garrett	3238	0	6	2	94	0	4	36
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SB Garrett	3241	0	0	0	13	0	0	48
SB Garrett	3242	0	1	0	26	0	1	46
SB Garrett	3243	1	2	0	26	0	2	44
SB Garrett	3244	1	2	1	27	0	1	44
SB Garrett	3245	0	2	2	57	0	0	44
SB Garrett	3246	0	0	0	-3	0	0	48
SB Garrett	3247	0	1	0	13	0	1	46
SB Garrett	3248	0	2	0	14	0	2	44
SB Garrett	3249	0	3	0	17	0	3	42
SB Garrett	3250	0	4	0	24	0	4	40
SB Garrett	3251	0	5	0	25	0	5	38
SB Garrett	3252	1	6	0	29	0	6	36
SB Garrett	3253	1	6	1	45	0	5	36
SB Garrett	3254	1	6	2	65	0	4	36
SB Garrett	3255	0	6	3	69	0	3	36
SB Garrett	3256	0	7	3	71	0	4	34
SB Garrett	3257	1	8	3	81	0	5	32
SB Garrett	3258	1	8	4	97	0	4	32
SB Garrett	3259	0	0	0	47	0	0	48
SB Garrett	3260	0	1	0	72	0	1	46
SB Garrett	3261	0	2	0	74	0	2	44
SB Garrett	3262	1	3	0	78	0	3	42
SB Garrett	3263	0	3	1	81	0	2	42
SB Garrett	3264	1	4	1	81	0	3	40
SB Garrett	3265	0	4	2	83	0	2	40
SB Garrett	3266	0	5	2	88	0	3	38
SB Garrett	3267	0	0	0	3	0	0	48
SB Garrett	3268	0	1	0	11	0	1	46
SB Garrett	3269	0	2	0	14	0	2	44
SB Garrett	3270	1	3	0	15	0	3	42

SB Garrett	3271	0	3	1	23	0	2	42
SB Garrett	3272	0	4	1	28	0	3	40
SB Garrett	3273	0	5	1	31	0	4	38
SB Garrett	3274	1	6	1	32	0	5	36
SB Garrett	3275	0	6	2	34	0	4	36
SB Garrett	3276	0	7	2	36	0	5	34
SB Garrett	3277	0	0	0	36	0	0	48
SB Garrett	3278	1	1	0	42	0	1	46
SB Garrett	3279	0	1	1	44	0	0	46
SB Garrett	3280	0	2	1	52	0	1	44
SB Garrett	3281	0	3	1	55	0	2	42
SB Garrett	3282	1	4	1	75	0	3	40
SB Garrett	3283	0	0	0	4	0	0	48
SB Garrett	3284	0	1	0	19	0	1	46
SB Garrett	3285	0	2	0	39	0	2	44
SB Garrett	3286	0	3	0	43	0	3	42
SB Garrett	3287	0	4	0	50	0	4	40
SB Garrett	3288	1	5	0	74	0	5	38
SB Garrett	3289	0	5	1	84	0	4	38
SB Garrett	3290	0	0	0	65	0	0	48
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SB Garrett	3292	0	2	0	81	0	2	44
SB Garrett	3293	0	3	0	97	0	3	42
EB Magee	4001	0	1	0	0	7	0	18
EB Magee	4002	0	1	0	0	2	0	13
EB Magee	4003	0	4	0	0	17	0	12
EB Magee	4004	1	5	0	0	17	0	10
EB Magee	4005	0	2	0	0	8	0	7
EB Magee	4006	1	2	0	0	9	0	15
EB Magee	4007	1	8	3	0	27	0	13
EB Magee	4008	0	5	0	0	17	0	9
EB Magee	4009	0	1	0	0	7	0	7
EB Magee	4010	0	11	2	0	22	0	5
EB Magee	4011	1	6	0	0	15	0	8
EB Magee	4012	0	1	0	0	1	0	4
EB Magee	4013	0	5	0	0	16	0	17
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EB Magee	4015	1	5	1	0	15	0	12
EB Magee	4016	0	4	1	0	11	0	10
EB Magee	4017	1	4	0	0	14	0	9

EB Magee	4018	0	2	0	0	8	0	7
EB Magee	4019	1	4	0	0	15	0	14
EB Magee	4020	0	6	1	0	14	0	12
EB Magee	4021	1	6	0	0	14	0	12
EB Magee	4022	1	7	3	0	14	0	13
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EB Magee	4024	0	11	2	0	20	0	7
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EB Magee	4027	0	10	2	0	28	0	6
EB Magee	4028	0	7	0	0	23	0	7
EB Magee	4029	0	7	0	0	20	0	4
EB Magee	4030	0	6	0	0	13	0	-1
EB Magee	4031	0	7	1	0	25	0	13
EB Magee	4032	1	8	4	0	21	0	13
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EB Magee	4036	0	8	2	0	11	0	3
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EB Magee	4038	0	10	0	0	18	0	-4
EB Magee	4039	1	3	0	0	5	0	-3
EB Magee	4040	0	3	1	0	1	0	-7
EB Magee	4041	1	11	1	0	31	0	7
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EB Magee	4043	0	12	2	0	28	0	2
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EB Magee	4050	1	9	2	0	27	0	8
EB Magee	4051	0	9	3	0	23	0	4
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EB Magee	4054	0	3	0	0	13	0	6
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EB Magee	4056	1	4	0	0	25	0	16
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EB Magee	4060	0	0	0	-1	0	0	29
EB Magee	4061	1	1	0	0	0	1	27
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EB Magee	4063	0	2	1	42	0	1	25
EB Magee	4064	0	3	1	47	0	2	23
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EB Magee	4066	1	5	1	68	0	4	19
EB Magee	4067	0	2	0	10	0	2	25
EB Magee	4068	0	3	0	32	0	3	23
EB Magee	4069	0	4	0	36	0	4	21
EB Magee	4070	0	5	0	63	0	5	19
EB Magee	4071	0	6	0	68	0	6	17
EB Magee	4072	0	7	1	72	0	6	15
EB Magee	4073	0	0	0	0	0	0	29
EB Magee	4074	0	1	0	24	0	1	27
EB Magee	4075	1	2	0	52	0	2	25
EB Magee	4076	1	2	0	54	0	2	25
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EB Magee	4079	0	2	1	17	0	1	25
EB Magee	4080	0	3	1	24	0	2	23
EB Magee	4081	0	4	0	64	0	4	21
EB Magee	4082	0	0	0	-1	0	0	29
EB Magee	4083	0	1	0	6	0	1	27
EB Magee	4084	0	2	0	16	0	2	25
EB Magee	4085	0	3	0	65	0	3	23
EB Magee	4086	0	0	0	21	0	0	29
EB Magee	4087	0	1	0	32	0	1	27
EB Magee	4088	0	2	1	33	0	1	25
EB Magee	4089	0	3	2	38	0	1	23
EB Magee	4090	1	4	2	38	0	2	21
EB Magee	4091	0	4	3	42	0	1	21
EB Magee	4092	1	5	3	67	0	2	19
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EB Magee	4095	0	1	0	1	0	1	27
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EB Magee	4098	1	4	2	29	0	2	21
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EB Magee	4100	1	5	2	46	0	3	19
EB Magee	4101	0	5	3	50	0	2	19
EB Magee	4102	0	6	2	56	0	4	17
EB Magee	4103	1	7	2	61	0	5	15
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EB Magee	4109	0	3	1	50	0	2	23
EB Magee	4110	0	4	1	55	0	3	21
EB Magee	4111	0	0	0	12	0	0	29
EB Magee	4112	0	1	1	19	0	0	27
EB Magee	4113	0	2	1	23	0	1	25
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EB Magee	4146	0	2	0	15	0	2	25
EB Magee	4147	0	3	0	21	0	3	23
EB Magee	4148	0	4	2	33	0	2	21
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EB Magee	4153	0	2	0	22	0	2	25
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EB Magee	4163	0	2	1	18	0	1	25
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EB Magee	4166	0	4	2	37	0	2	21
EB Magee	4167	0	5	2	63	0	3	19
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EB Magee	4170	0	2	0	5	0	2	25
EB Magee	4171	0	3	0	8	0	3	23
EB Magee	4172	1	4	0	15	0	4	21
EB Magee	4173	0	4	1	18	0	3	21
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EB Magee	4176	0	7	1	28	0	6	15
EB Magee	4177	1	8	1	29	0	7	13

EB Magee	4178	0	9	4	53	0	5	11
EB Magee	4179	0	0	0	-5	0	0	29
EB Magee	4180	0	1	2	3	0	-1	27
EB Magee	4181	0	2	1	8	0	1	25
EB Magee	4182	0	3	1	13	0	2	23
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EB Magee	4184	0	5	0	19	0	5	19
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EB Magee	4187	0	6	2	37	0	4	17
EB Magee	4188	1	0	0	7	0	0	29
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EB Magee	4192	0	3	1	19	0	2	23
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EB Magee	4195	0	0	0	18	0	0	29
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EB Magee	4198	0	2	1	28	0	1	25
EB Magee	4199	0	0	0	3	0	0	29
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EB Magee	4201	0	2	0	13	0	2	25
EB Magee	4202	0	3	0	15	0	3	23
EB Magee	4203	0	4	0	24	0	4	21
EB Magee	4204	0	5	0	28	0	5	19
EB Magee	4205	0	6	0	46	0	6	17
EB Magee	4206	0	7	0	52	0	7	15
EB Magee	4207	0	0	0	4	0	0	29
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EB Magee	4210	0	2	1	21	0	1	25
EB Magee	4211	0	3	1	35	0	2	23
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EB Magee	4213	1	5	2	43	0	3	19
EB Magee	4214	0	5	3	51	0	2	19
EB Magee	4215	0	6	3	63	0	3	17
EB Magee	4216	1	7	3	64	0	4	15
EB Magee	4217	0	0	0	-6	0	0	29

EB Magee	4218	0	1	0	-5	0	1	27
EB Magee	4219	0	2	0	-3	0	2	25
EB Magee	4220	0	3	0	1	0	3	23
EB Magee	4221	0	4	0	10	0	4	21
EB Magee	4222	0	5	2	41	0	3	19
EB Magee	4223	1	0	0	-1	0	0	29
EB Magee	4224	0	0	1	6	0	-1	29
EB Magee	4225	0	1	1	24	0	0	27
EB Magee	4226	0	2	1	26	0	1	25
EB Magee	4227	0	3	1	29	0	2	23
EB Magee	4228	0	4	1	32	0	3	21
EB Magee	4229	1	5	1	40	0	4	19
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EB Magee	4231	0	6	2	58	0	4	17
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EB Magee	4238	1	7	1	23	0	6	15
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EB Magee	4251	0	1	0	-5	0	1	27
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EB Magee	4253	0	3	0	7	0	3	23
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EB Magee	4256	0	6	0	57	0	6	17
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EB Magee	4259	0	1	2	13	0	-1	27
EB Magee	4260	0	2	2	17	0	0	25
EB Magee	4261	0	3	2	21	0	1	23
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EB Magee	4264	0	6	2	29	0	4	17
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EB Magee	4267	0	9	2	36	0	7	11
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EB Magee	4270	1	12	2	44	0	10	5
EB Magee	4271	0	0	0	1	0	0	29
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EB Magee	4274	0	3	2	11	0	1	23
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EB Magee	4277	0	6	2	21	0	4	17
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EB Magee	4295	1	16	4	52	0	12	-3
EB Magee	4296	0	4	1	17	0	3	21
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EB Magee	4300	0	8	1	25	0	7	13
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EB Magee	4302	0	10	1	31	0	9	9
EB Magee	4303	0	0	0	-2	0	0	29
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EB Magee	4305	0	2	0	4	0	2	25
EB Magee	4306	0	3	0	8	0	3	23
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EB Magee	4311	0	7	1	18	0	6	15
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EB Magee	4316	0	2	0	-1	0	2	25
EB Magee	4317	0	3	0	6	0	3	23
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EB Magee	4319	0	5	0	10	0	5	19
EB Magee	4320	1	6	0	12	0	6	17
EB Magee	4321	0	6	1	22	0	5	17
EB Magee	4322	0	7	1	26	0	6	15
EB Magee	4323	1	8	1	32	0	7	13
EB Magee	4324	1	8	2	42	0	6	13
EB Magee	4325	0	8	3	51	0	5	13
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EB Magee	4328	1	11	4	61	0	7	7
EB Magee	4329	0	0	0	5	0	0	29
EB Magee	4330	0	1	0	20	0	1	27
EB Magee	4331	0	2	0	23	0	2	25
EB Magee	4332	0	3	0	29	0	3	23
EB Magee	4333	0	4	0	31	0	4	21
EB Magee	4334	0	5	0	33	0	5	19
EB Magee	4335	0	6	0	35	0	6	17
EB Magee	4336	0	7	0	37	0	7	15
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EB Magee	4338	1	9	1	43	0	8	11
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EB Magee	4340	0	9	3	47	0	6	11
EB Magee	4341	0	0	1	9	0	-1	29
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EB Magee	4343	0	2	0	13	0	2	25
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EB Magee	4347	0	5	1	27	0	4	19
EB Magee	4348	0	6	1	32	0	5	17
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EB Magee	4350	0	8	2	61	0	6	13
EB Magee	4351	0	0	0	-5	0	0	29
EB Magee	4352	0	1	0	-3	0	1	27
EB Magee	4353	0	2	0	1	0	2	25
EB Magee	4354	0	3	0	3	0	3	23
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EB Magee	4356	0	4	1	24	0	3	21
EB Magee	4357	0	5	1	30	0	4	19
EB Magee	4358	1	6	1	32	0	5	17
EB Magee	4359	1	6	2	34	0	4	17
EB Magee	4360	0	6	3	42	0	3	17
EB Magee	4361	0	7	3	53	0	4	15
EB Magee	4362	0	0	0	-5	0	0	29
EB Magee	4363	0	1	0	8	0	1	27
EB Magee	4364	0	2	0	11	0	2	25
EB Magee	4365	0	3	1	36	0	2	23
EB Magee	4366	0	4	1	48	0	3	21
EB Magee	4367	0	0	0	-2	0	0	29
EB Magee	4368	0	1	0	1	0	1	27
EB Magee	4369	0	2	0	3	0	2	25
EB Magee	4370	0	3	0	6	0	3	23
EB Magee	4371	0	4	0	26	0	4	21
EB Magee	4372	0	5	0	33	0	5	19
EB Magee	4373	0	6	0	40	0	6	17
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EB Magee	4375	0	7	2	56	0	5	15
EB Magee	4376	0	0	0	-6	0	0	29
EB Magee	4377	0	1	0	-4	0	1	27

EB Magee	4378	0	2	1	6	0	1	25
EB Magee	4379	0	3	1	9	0	2	23
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EB Magee	4381	0	5	0	31	0	5	19
EB Magee	4382	1	6	1	33	0	5	17
EB Magee	4383	1	7	0	35	0	7	15
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EB Magee	4385	0	8	1	39	0	7	13
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EB Magee	4387	1	9	2	40	0	7	11
EB Magee	4388	0	9	3	59	0	6	11
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EB Magee	4395	0	5	2	45	0	3	19
WB Magee	5001	0	4	6	0	19	0	16
WB Magee	5002	0	1	6	0	13	0	16
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WB Magee	5004	0	13	1	0	17	0	-8
WB Magee	5005	0	4	0	0	4	0	-3
WB Magee	5006	0	2	0	0	8	0	9
WB Magee	5007	0	5	1	0	24	0	-13
WB Magee	5008	0	0	0	0	14	0	-13
WB Magee	5009	0	1	0	0	12	0	-17
WB Magee	5010	1	8	2	0	23	0	12
WB Magee	5011	0	8	2	0	21	0	10
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WB Magee	5013	0	4	0	0	10	0	7
WB Magee	5014	0	4	2	0	22	0	16
WB Magee	5015	0	2	5	0	17	0	11
WB Magee	5016	0	2	4	0	16	0	10
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WB Magee	5018	0	3	3	0	11	0	3
WB Magee	5019	0	3	3	0	9	0	1
WB Magee	5020	0	5	0	0	20	0	19
WB Magee	5021	0	6	0	0	18	0	15
WB Magee	5022	0	7	0	0	17	0	12

WB Magee	5023	0	6	0	0	13	0	10
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WB Magee	5025	0	13	7	0	36	0	3
WB Magee	5026	0	5	1	0	15	0	-2
WB Magee	5027	0	6	0	0	17	0	-2
WB Magee	5028	0	5	3	0	23	0	18
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WB Magee	5030	0	4	0	0	14	0	11
WB Magee	5031	0	4	0	0	13	0	10
WB Magee	5032	0	10	2	0	36	0	9
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WB Magee	5034	0	11	0	0	32	0	3
WB Magee	5035	1	10	0	0	28	0	1
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WB Magee	5040	0	9	5	0	19	0	8
WB Magee	5041	0	2	2	0	26	0	19
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WB Magee	5043	0	1	0	0	19	0	14
WB Magee	5044	0	2	0	0	16	0	9
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WB Magee	5046	0	0	0	0	14	0	14
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WB Magee	5048	0	0	0	0	10	0	9
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WB Magee	5055	1	3	0	0	18	0	17
WB Magee	5056	0	7	1	0	31	0	12
WB Magee	5057	1	0	0	0	13	0	20
WB Magee	5058	0	0	1	0	12	0	19
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WB Magee	5060	0	2	0	0	9	0	13
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WB Magee	5065	1	6	1	0	24	0	15
WB Magee	5066	0	6	2	0	22	0	13
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WB Magee	5070	0	2	0	0	16	0	18
WB Magee	5071	0	1	1	0	13	0	21
WB Magee	5072	0	2	1	0	11	0	17
WB Magee	5073	1	6	4	0	26	0	12
WB Magee	5074	0	3	0	0	14	0	15
WB Magee	5075	1	4	0	0	14	0	13
WB Magee	5076	0	4	3	0	32	0	18
WB Magee	5077	1	1	0	0	25	0	17
WB Magee	5078	1	1	1	0	22	0	14
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WB Magee	5080	0	2	2	29	0	0	25
WB Magee	5081	0	3	2	40	0	1	23
WB Magee	5082	0	4	2	45	0	2	21
WB Magee	5083	0	5	4	54	0	1	19
WB Magee	5084	0	6	4	55	0	2	17
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WB Magee	5086	0	2	2	18	0	0	25
WB Magee	5087	0	3	2	51	0	1	23
WB Magee	5088	0	0	4	4	0	-4	29
WB Magee	5089	0	1	4	6	0	-3	27
WB Magee	5090	0	2	5	13	0	-3	25
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WB Magee	5093	0	4	6	17	0	-2	21
WB Magee	5094	0	5	6	18	0	-1	19
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WB Magee	5100	0	11	6	42	0	5	7
WB Magee	5101	0	12	6	44	0	6	5
WB Magee	5102	0	13	6	48	0	7	3

WB Magee	5103	1	14	6	48	0	8	1
WB Magee	5104	0	14	7	50	0	7	1
WB Magee	5105	0	15	8	57	0	7	-1
WB Magee	5106	0	5	1	13	0	4	19
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WB Magee	5108	0	6	2	18	0	4	17
WB Magee	5109	0	7	3	30	0	4	15
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WB Magee	5111	0	8	4	46	0	4	13
WB Magee	5112	1	9	4	48	0	5	11
WB Magee	5113	0	1	0	1	0	1	27
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WB Magee	5115	0	3	3	15	0	0	23
WB Magee	5116	0	4	3	36	0	1	21
WB Magee	5117	1	5	1	63	0	4	19
WB Magee	5118	0	0	0	-4	0	0	29
WB Magee	5119	1	1	0	-3	0	1	27
WB Magee	5120	0	1	1	-2	0	0	27
WB Magee	5121	0	2	1	3	0	1	25
WB Magee	5122	0	3	2	12	0	1	23
WB Magee	5123	0	4	2	29	0	2	21
WB Magee	5124	0	5	2	36	0	3	19
WB Magee	5125	0	6	2	39	0	4	17
WB Magee	5126	0	7	2	44	0	5	15
WB Magee	5127	0	1	2	6	0	-1	27
WB Magee	5128	0	2	2	8	0	0	25
WB Magee	5129	1	3	2	10	0	1	23
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WB Magee	5131	0	4	4	32	0	0	21
WB Magee	5132	0	5	4	47	0	1	19
WB Magee	5133	0	0	0	-9	0	0	29
WB Magee	5134	0	1	0	-1	0	1	27
WB Magee	5135	0	2	3	11	0	-1	25
WB Magee	5136	0	3	3	14	0	0	23
WB Magee	5137	0	4	3	16	0	1	21
WB Magee	5138	0	5	2	17	0	3	19
WB Magee	5139	0	6	2	22	0	4	17
WB Magee	5140	0	7	2	25	0	5	15
WB Magee	5141	0	8	2	26	0	6	13
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WB Magee	5143	0	10	1	32	0	9	9
WB Magee	5144	1	11	3	43	0	8	7
WB Magee	5145	0	11	7	56	0	4	7
WB Magee	5146	0	0	1	7	0	-1	29
WB Magee	5147	0	1	1	10	0	0	27
WB Magee	5148	0	2	1	12	0	1	25
WB Magee	5149	1	3	1	22	0	2	23
WB Magee	5150	0	3	3	26	0	0	23
WB Magee	5151	0	4	3	28	0	1	21
WB Magee	5152	0	5	6	44	0	-1	19
WB Magee	5153	0	6	7	45	0	-1	17
WB Magee	5154	0	1	0	-2	0	1	27
WB Magee	5155	0	2	0	0	0	2	25
WB Magee	5156	0	3	0	2	0	3	23
WB Magee	5157	0	4	0	4	0	4	21
WB Magee	5158	0	5	1	23	0	4	19
WB Magee	5159	0	6	1	30	0	5	17
WB Magee	5160	1	7	1	30	0	6	15
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WB Magee	5162	0	7	3	40	0	4	15
WB Magee	5163	0	0	0	-4	0	0	29
WB Magee	5164	0	1	1	9	0	0	27
WB Magee	5165	0	2	2	13	0	0	25
WB Magee	5166	0	3	2	20	0	1	23
WB Magee	5167	0	4	1	28	0	3	21
WB Magee	5168	1	3	0	4	0	3	23
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WB Magee	5170	0	4	1	13	0	3	21
WB Magee	5171	0	5	4	27	0	1	19
WB Magee	5172	0	6	6	41	0	0	17
WB Magee	5173	0	7	7	47	0	0	15
WB Magee	5174	0	8	7	52	0	1	13
WB Magee	5175	0	9	7	60	0	2	11
WB Magee	5176	0	10	7	64	0	3	9
WB Magee	5177	0	11	7	66	0	4	7
WB Magee	5178	0	12	7	68	0	5	5
WB Magee	5179	0	0	0	30	0	0	29
WB Magee	5180	0	1	0	32	0	1	27
WB Magee	5181	0	2	0	34	0	2	25
WB Magee	5182	0	3	1	40	0	2	23

WB Magee	5183	1	4	1	42	0	3	21
WB Magee	5184	0	4	3	49	0	1	21
WB Magee	5185	0	5	4	51	0	1	19
WB Magee	5186	0	0	0	19	0	0	29
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WB Magee	5188	0	2	1	37	0	1	25
WB Magee	5189	0	3	1	45	0	2	23
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WB Magee	5191	0	4	1	59	0	3	21
WB Magee	5192	0	5	1	60	0	4	19
WB Magee	5193	0	6	1	61	0	5	17
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WB Magee	5196	0	9	1	64	0	8	11
WB Magee	5197	0	10	1	65	0	9	9
WB Magee	5198	0	11	1	66	0	10	7
WB Magee	5199	0	12	1	68	0	11	5
WB Magee	5200	0	0	0	-8	0	0	29
WB Magee	5201	0	1	0	-7	0	1	27
WB Magee	5202	1	2	0	-7	0	2	25
WB Magee	5203	1	2	1	-4	0	1	25
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WB Magee	5205	0	3	3	48	0	0	23
WB Magee	5206	0	4	3	52	0	1	21
WB Magee	5207	0	0	0	8	0	0	29
WB Magee	5208	0	1	0	14	0	1	27
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WB Magee	5217	1	9	1	61	0	8	11
WB Magee	5218	0	0	0	-8	0	0	29
WB Magee	5219	0	1	0	4	0	1	27
WB Magee	5220	0	2	0	6	0	2	25
WB Magee	5221	0	3	0	8	0	3	23
WB Magee	5222	0	4	0	11	0	4	21

WB Magee	5223	1	5	0	16	0	5	19
WB Magee	5224	0	5	1	16	0	4	19
WB Magee	5225	0	6	1	25	0	5	17
WB Magee	5226	0	7	1	28	0	6	15
WB Magee	5227	1	8	3	37	0	5	13
WB Magee	5228	0	2	0	8	0	2	25
WB Magee	5229	0	3	0	34	0	3	23
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WB Magee	5231	0	5	1	41	0	4	19
WB Magee	5232	0	6	2	44	0	4	17
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WB Magee	5239	0	1	1	15	0	0	27
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WB Magee	5241	0	0	0	-7	0	0	29
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WB Magee	5243	1	2	0	0	0	2	25
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WB Magee	5250	0	1	2	25	0	-1	27
WB Magee	5251	0	2	2	27	0	0	25
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WB Magee	5259	0	7	3	90	0	4	15
WB Magee	5260	1	0	0	7	0	0	29
WB Magee	5261	0	0	1	10	0	-1	29
WB Magee	5262	0	1	2	20	0	-1	27

WB Magee	5263	0	0	0	-5	0	0	29
WB Magee	5264	1	1	1	3	0	0	27
WB Magee	5265	0	1	2	5	0	-1	27
WB Magee	5266	0	2	3	18	0	-1	25
WB Magee	5267	0	3	2	21	0	1	23
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WB Magee	5269	0	5	3	26	0	2	19
WB Magee	5270	0	6	3	44	0	3	17
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WB Magee	5272	0	7	4	46	0	3	15
WB Magee	5273	1	8	4	48	0	4	13
WB Magee	5274	0	8	6	64	0	2	13
WB Magee	5275	0	0	0	-6	0	0	29
WB Magee	5276	0	1	2	9	0	-1	27
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WB Magee	5278	0	3	2	16	0	1	23
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WB Magee	5283	0	7	2	41	0	5	15
WB Magee	5284	0	8	1	49	0	7	13
WB Magee	5285	0	0	0	-10	0	0	29
WB Magee	5286	0	1	0	5	0	1	27
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WB Magee	5291	0	0	2	11	0	-2	29
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WB Magee	5293	0	2	3	21	0	-1	25
WB Magee	5294	0	3	3	24	0	0	23
WB Magee	5295	0	4	3	33	0	1	21
WB Magee	5296	0	5	3	35	0	2	19
WB Magee	5297	1	6	2	60	0	4	17
WB Magee	5298	0	0	0	-8	0	0	29
WB Magee	5299	0	1	0	-5	0	1	27
WB Magee	5300	0	2	0	16	0	2	25
WB Magee	5301	0	3	1	27	0	2	23
WB Magee	5302	0	4	0	51	0	4	21

WB Magee	5303	0	5	0	57	0	5	19
WB Magee	5304	0	6	0	63	0	6	17
WB Magee	5305	0	0	1	-6	0	-1	29
WB Magee	5306	0	1	2	3	0	-1	27
WB Magee	5307	0	2	4	39	0	-2	25
WB Magee	5308	0	3	4	41	0	-1	23
WB Magee	5309	0	4	5	42	0	-1	21
WB Magee	5310	0	5	4	48	0	1	19
WB Magee	5311	1	6	4	48	0	2	17
WB Magee	5312	1	6	6	50	0	0	17
WB Magee	5313	0	6	7	54	0	-1	17
WB Magee	5314	1	7	4	62	0	3	15
WB Magee	5315	0	7	5	63	0	2	15
WB Magee	5316	0	0	1	37	0	-1	29
WB Magee	5317	0	1	1	53	0	0	27
WB Magee	5318	0	0	1	6	0	-1	29
WB Magee	5319	0	1	0	17	0	1	27
WB Magee	5320	0	2	0	33	0	2	25
WB Magee	5321	1	3	0	35	0	3	23
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WB Magee	5323	0	4	1	46	0	3	21
WB Magee	5324	0	5	1	53	0	4	19
WB Magee	5325	0	6	1	67	0	5	17
WB Magee	5326	0	0	0	-7	0	0	29
WB Magee	5327	0	1	2	10	0	-1	27
WB Magee	5328	0	2	2	29	0	0	25
WB Magee	5329	0	3	1	43	0	2	23
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WB Magee	5331	0	5	0	49	0	5	19
WB Magee	5332	0	6	0	60	0	6	17
WB Magee	5333	1	7	0	64	0	7	15
WB Magee	5334	0	0	0	-5	0	0	29
WB Magee	5335	0	1	1	11	0	0	27
WB Magee	5336	0	2	1	13	0	1	25
WB Magee	5337	1	3	1	13	0	2	23
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WB Magee	5340	0	1	0	2	0	1	27
WB Magee	5341	0	2	1	32	0	1	25
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WB Magee	5343	1	4	0	46	0	4	21
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WB Magee	5345	0	0	0	21	0	0	29
WB Magee	5346	0	1	0	23	0	1	27
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WB Magee	5348	1	3	1	54	0	2	23
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WB Magee	5350	0	0	0	-5	0	0	29
WB Magee	5351	0	1	0	1	0	1	27
WB Magee	5352	0	2	0	41	0	2	25
WB Magee	5353	0	3	0	50	0	3	23
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WB Magee	5355	0	4	1	57	0	3	21
WB Magee	5356	1	5	1	57	0	4	19
WB Magee	5357	1	5	3	62	0	2	19
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WB Magee	5359	0	6	5	67	0	1	17
WB Magee	5360	0	0	0	5	0	0	29
WB Magee	5361	0	1	1	15	0	0	27
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WB Magee	5363	0	3	1	18	0	2	23
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WB Magee	5366	0	6	1	33	0	5	17
WB Magee	5367	0	7	1	36	0	6	15
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WB Magee	5369	0	9	1	49	0	8	11
WB Magee	5370	0	0	0	-5	0	0	29
WB Magee	5371	0	1	0	1	0	1	27
WB Magee	5372	1	2	1	13	0	1	25
WB Magee	5373	0	2	2	32	0	0	25
WB Magee	5374	1	0	0	-6	0	0	29
WB Magee	5375	0	0	1	2	0	-1	29
WB Magee	5376	0	1	1	21	0	0	27
WB Magee	5377	0	2	1	49	0	1	25
WB Magee	5378	0	3	1	51	0	2	23
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WB Magee	5380	0	5	1	55	0	4	19
WB Magee	5381	0	6	1	57	0	5	17
WB Magee	5382	0	0	0	2	0	0	29

WB Magee	5383	1	1	0	2	0	1	27
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WB Magee	5385	0	2	3	53	0	-1	25
WB Magee	5386	0	3	3	55	0	0	23
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NB La Canada	6006	0	4	2	32	0	2	25
NB La Canada	6007	0	0	0	-4	0	0	34
NB La Canada	6008	0	1	0	0	0	1	32
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NB La Canada	6017	0	3	1	5	0	2	28
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NB La Canada	6039	0	1	1	3	0	0	34
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NB La Canada	6064	0	17	3	50	0	14	3
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NB La Canada	6075	0	2	0	3	0	2	36
NB La Canada	6076	1	3	0	24	0	3	34

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NB La Canada	6079	0	2	2	48	0	0	32
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NB La Canada	6101	0	0	0	-2	0	0	45
NB La Canada	6102	1	1	0	6	0	1	43
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NB La Canada	6119	1	3	2	15	0	1	30
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NB La Canada	6126	0	8	4	35	0	4	20
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NB La Canada	6130	0	1	0	5	0	1	34
NB La Canada	6131	0	2	0	19	0	2	32
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NB La Canada	6138	0	9	0	45	0	9	18
NB La Canada	6139	0	10	0	47	0	10	16
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NB La Canada	6142	0	12	1	51	0	11	12
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NB La Canada	6145	0	1	2	-1	0	-1	46
NB La Canada	6146	0	2	1	17	0	1	44
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NB La Canada	6316	0	6	2	27	0	4	24

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NB La Canada	6356	0	14	3	31	0	11	8

NB La Canada	6357	0	0	0	-4	0	0	40
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NB La Canada	6359	0	2	0	2	0	2	36
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NB La Canada	6395	1	18	2	0	36	0	0
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NB La Canada	6436	0	2	0	0	35	0	31

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NB La Canada	6476	0	2	1	0	11	0	7

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NB La Canada	6497	0	2	0	0	25	0	21
NB La Canada	6498	0	7	2	0	37	0	23
NB La Canada	6499	1	8	2	0	37	0	21
NB La Canada	6500	0	4	0	0	29	0	21
NB La Canada	6501	1	5	0	0	27	0	17
NB La Canada	6502	0	3	1	0	25	0	19
NB La Canada	6503	0	0	0	0	21	0	21
NB La Canada	6504	0	1	0	0	19	0	17
NB La Canada	6505	0	0	0	0	12	0	12
NB La Canada	6506	0	5	1	0	42	0	32
NB La Canada	6507	0	3	0	0	35	0	29
NB La Canada	6508	0	3	0	0	33	0	27
NB La Canada	6509	0	3	0	0	31	0	25
NB La Canada	6510	0	3	0	0	29	0	23
NB La Canada	6511	0	1	1	0	24	0	22
NB La Canada	6512	0	0	0	0	20	0	20
NB La Canada	6513	1	1	0	0	18	0	16
NB La Canada	6514	0	0	0	0	11	0	11
NB La Canada	6515	0	4	1	0	48	0	40
NB La Canada	6516	0	2	0	0	43	0	39

NB La Canada	6517	0	1	0	0	41	0	39
NB La Canada	6518	1	2	0	0	41	0	37
NB La Canada	6519	0	0	0	0	30	0	30
NB La Canada	6520	0	0	1	0	25	0	25
NB La Canada	6521	0	1	2	0	21	0	19
NB La Canada	6522	0	1	1	0	15	0	13
NB La Canada	6523	0	1	0	0	13	0	11
NB La Canada	6524	0	2	0	0	11	0	7
NB La Canada	6525	0	2	1	0	9	0	5
NB La Canada	6526	0	3	1	0	7	0	1
NB La Canada	6527	0	0	0	0	23	0	23
NB La Canada	6528	0	0	0	0	11	0	11
NB La Canada	6529	0	1	0	0	9	0	7
NB La Canada	6530	0	11	3	0	38	0	16
NB La Canada	6531	0	11	2	0	35	0	13
NB La Canada	6532	1	9	0	0	28	0	10
NB La Canada	6533	0	7	1	0	23	0	9
NB La Canada	6534	0	7	1	0	21	0	7
NB La Canada	6535	0	7	1	0	19	0	5
NB La Canada	6536	1	6	2	0	16	0	4
NB La Canada	6537	0	3	0	0	37	0	31
NB La Canada	6538	0	3	0	0	28	0	22
NB La Canada	6539	0	0	0	0	19	0	19
NB La Canada	6540	0	0	0	0	31	0	31
NB La Canada	6541	1	1	0	0	29	0	27
NB La Canada	6542	0	1	1	0	27	0	25
NB La Canada	6543	0	2	1	0	25	0	21
NB La Canada	6544	0	3	1	0	23	0	17
NB La Canada	6545	0	0	0	0	14	0	14
NB La Canada	6546	0	1	0	0	12	0	10
NB La Canada	6547	0	2	1	0	10	0	6
NB La Canada	6548	1	3	1	0	8	0	2
NB La Canada	6549	0	2	2	0	6	0	2
NB La Canada	6550	0	10	0	0	31	0	11
NB La Canada	6551	1	5	0	0	20	0	10
NB La Canada	6552	1	4	1	0	18	0	10
NB La Canada	6553	0	1	1	0	12	0	10
NB La Canada	6554	0	1	1	0	10	0	8
NB La Canada	6555	0	9	0	0	32	0	14
NB La Canada	6556	0	8	0	0	30	0	14

NB La Canada	6557	0	2	0	0	18	0	14
NB La Canada	6558	0	2	0	0	13	0	9
NB La Canada	6559	0	7	1	0	31	0	17
NB La Canada	6560	1	7	1	0	29	0	15
NB La Canada	6561	0	5	3	0	25	0	15
NB La Canada	6562	0	5	2	0	23	0	13
NB La Canada	6563	0	1	0	0	36	0	34
NB La Canada	6564	0	1	0	0	32	0	30
NB La Canada	6565	0	1	0	0	30	0	28
NB La Canada	6566	0	1	0	0	26	0	24
NB La Canada	6567	1	2	0	0	24	0	20
NB La Canada	6568	0	0	0	0	17	0	17
NB La Canada	6569	0	1	0	0	15	0	13
NB La Canada	6570	1	13	2	0	33	0	7
NB La Canada	6571	1	1	0	0	21	0	19
NB La Canada	6572	1	11	6	0	42	0	20
NB La Canada	6573	0	11	7	0	40	0	18
NB La Canada	6574	0	12	7	0	38	0	14
NB La Canada	6575	0	7	1	0	29	0	15
NB La Canada	6576	1	4	0	0	23	0	15
NB La Canada	6577	0	3	0	0	21	0	15
NB La Canada	6578	0	7	2	0	37	0	23
NB La Canada	6579	1	8	2	0	36	0	20
NB La Canada	6580	0	8	2	0	35	0	19
NB La Canada	6581	0	8	1	0	33	0	17
NB La Canada	6582	0	8	1	0	31	0	15
NB La Canada	6583	0	8	1	0	29	0	13
NB La Canada	6584	1	5	1	0	21	0	11
NB La Canada	6585	0	4	1	0	17	0	9
NB La Canada	6586	0	4	1	0	15	0	7
NB La Canada	6587	0	4	1	0	13	0	5
SB La Canada	7001	1	0	0	17	0	0	59
SB La Canada	7002	0	0	1	32	0	-1	59
SB La Canada	7003	0	1	1	35	0	0	57
SB La Canada	7004	0	0	0	-6	0	0	60
SB La Canada	7005	0	1	0	-1	0	1	58
SB La Canada	7006	0	2	0	2	0	2	56
SB La Canada	7007	0	3	0	15	0	3	54
SB La Canada	7008	0	0	0	-5	0	0	50
SB La Canada	7009	0	1	0	-2	0	1	48

SB La Canada	7010	0	2	0	0	0	2	46
SB La Canada	7011	0	3	0	3	0	3	44
SB La Canada	7012	1	4	0	3	0	4	42
SB La Canada	7013	0	4	1	8	0	3	42
SB La Canada	7014	0	5	1	11	0	4	40
SB La Canada	7015	0	6	1	24	0	5	38
SB La Canada	7016	0	0	1	-2	0	-1	53
SB La Canada	7017	0	1	1	-1	0	0	51
SB La Canada	7018	0	2	0	11	0	2	49
SB La Canada	7019	1	3	0	11	0	3	47
SB La Canada	7020	0	3	1	14	0	2	47
SB La Canada	7021	0	4	1	17	0	3	45
SB La Canada	7022	0	5	1	19	0	4	43
SB La Canada	7023	0	6	1	22	0	5	41
SB La Canada	7024	1	7	2	34	0	5	39
SB La Canada	7025	0	0	0	-6	0	0	47
SB La Canada	7026	0	1	0	25	0	1	45
SB La Canada	7027	0	0	0	-4	0	0	51
SB La Canada	7028	0	1	0	-1	0	1	49
SB La Canada	7029	0	2	0	1	0	2	47
SB La Canada	7030	0	3	0	3	0	3	45
SB La Canada	7031	1	4	1	5	0	3	43
SB La Canada	7032	1	5	1	9	0	4	41
SB La Canada	7033	0	0	0	0	0	0	56
SB La Canada	7034	0	1	0	5	0	1	54
SB La Canada	7035	0	2	1	10	0	1	52
SB La Canada	7036	0	3	2	11	0	1	50
SB La Canada	7037	0	4	2	17	0	2	48
SB La Canada	7038	0	5	0	28	0	5	46
SB La Canada	7039	0	0	0	-4	0	0	40
SB La Canada	7040	0	1	0	-1	0	1	38
SB La Canada	7041	0	2	0	1	0	2	36
SB La Canada	7042	0	3	0	2	0	3	34
SB La Canada	7043	1	4	0	5	0	4	32
SB La Canada	7044	0	4	1	6	0	3	32
SB La Canada	7045	0	5	2	10	0	3	30
SB La Canada	7046	0	0	2	3	0	-2	52
SB La Canada	7047	0	1	2	4	0	-1	50
SB La Canada	7048	0	2	1	18	0	1	48
SB La Canada	7049	1	3	0	30	0	3	46

SB La Canada	7050	1	3	1	31	0	2	46
SB La Canada	7051	0	3	2	33	0	1	46
SB La Canada	7052	0	4	2	41	0	2	44
SB La Canada	7053	1	0	0	5	0	0	45
SB La Canada	7054	0	0	1	7	0	-1	45
SB La Canada	7055	0	1	1	8	0	0	43
SB La Canada	7056	0	2	2	18	0	0	41
SB La Canada	7057	0	3	2	22	0	1	39
SB La Canada	7058	0	4	2	24	0	2	37
SB La Canada	7059	0	5	2	25	0	3	35
SB La Canada	7060	0	6	2	28	0	4	33
SB La Canada	7061	0	0	0	-1	0	0	59
SB La Canada	7062	0	1	0	1	0	1	57
SB La Canada	7063	0	2	0	3	0	2	55
SB La Canada	7064	0	3	0	9	0	3	53
SB La Canada	7065	0	4	1	13	0	3	51
SB La Canada	7066	0	5	1	15	0	4	49
SB La Canada	7067	1	6	1	18	0	5	47
SB La Canada	7068	0	0	0	-6	0	0	49
SB La Canada	7069	0	1	0	-5	0	1	47
SB La Canada	7070	0	2	0	-4	0	2	45
SB La Canada	7071	0	3	0	2	0	3	43
SB La Canada	7072	1	4	0	2	0	4	41
SB La Canada	7073	0	4	1	3	0	3	41
SB La Canada	7074	1	5	1	10	0	4	39
SB La Canada	7075	0	5	2	19	0	3	39
SB La Canada	7076	1	6	2	19	0	4	37
SB La Canada	7077	0	0	0	7	0	0	45
SB La Canada	7078	1	1	0	11	0	1	43
SB La Canada	7079	0	1	1	14	0	0	43
SB La Canada	7080	0	2	2	17	0	0	41
SB La Canada	7081	0	3	2	21	0	1	39
SB La Canada	7082	0	4	2	23	0	2	37
SB La Canada	7083	0	5	2	27	0	3	35
SB La Canada	7084	0	6	2	31	0	4	33
SB La Canada	7085	1	7	2	31	0	5	31
SB La Canada	7086	0	0	0	-5	0	0	45
SB La Canada	7087	0	1	0	-3	0	1	43
SB La Canada	7088	0	2	0	-1	0	2	41
SB La Canada	7089	0	3	0	2	0	3	39

SB La Canada	7090	1	4	0	5	0	4	37
SB La Canada	7091	0	5	0	8	0	5	35
SB La Canada	7092	1	5	1	14	0	4	35
SB La Canada	7093	0	5	2	17	0	3	35
SB La Canada	7094	0	6	2	19	0	4	33
SB La Canada	7095	0	7	3	21	0	4	31
SB La Canada	7096	0	8	3	23	0	5	29
SB La Canada	7097	0	9	3	24	0	6	27
SB La Canada	7098	1	10	3	29	0	7	25
SB La Canada	7099	0	10	4	40	0	6	25
SB La Canada	7100	0	0	0	-5	0	0	42
SB La Canada	7101	0	1	0	-3	0	1	40
SB La Canada	7102	0	2	0	2	0	2	38
SB La Canada	7103	0	3	0	6	0	3	36
SB La Canada	7104	0	4	0	8	0	4	34
SB La Canada	7105	0	5	0	19	0	5	32
SB La Canada	7106	0	0	0	0	0	0	38
SB La Canada	7107	0	1	0	1	0	1	36
SB La Canada	7108	0	2	0	3	0	2	34
SB La Canada	7109	1	3	0	6	0	3	32
SB La Canada	7110	0	3	3	27	0	0	32
SB La Canada	7111	1	4	3	35	0	1	30
SB La Canada	7112	0	4	4	36	0	0	30
SB La Canada	7113	0	0	0	1	0	0	45
SB La Canada	7114	0	1	0	7	0	1	43
SB La Canada	7115	0	2	0	9	0	2	41
SB La Canada	7116	1	3	0	15	0	3	39
SB La Canada	7117	0	0	1	0	0	-1	41
SB La Canada	7118	0	1	1	1	0	0	39
SB La Canada	7119	0	0	0	-3	0	0	48
SB La Canada	7120	0	1	0	-1	0	1	46
SB La Canada	7121	0	2	0	1	0	2	44
SB La Canada	7122	1	3	0	2	0	3	42
SB La Canada	7123	0	3	1	4	0	2	42
SB La Canada	7124	0	4	1	8	0	3	40
SB La Canada	7125	0	0	0	1	0	0	39
SB La Canada	7126	0	1	1	11	0	0	37
SB La Canada	7127	0	2	1	17	0	1	35
SB La Canada	7128	0	3	1	19	0	2	33
SB La Canada	7129	0	0	0	-5	0	0	46

SB La Canada	7130	0	1	0	15	0	1	44
SB La Canada	7131	1	2	0	15	0	2	42
SB La Canada	7132	1	2	1	19	0	1	42
SB La Canada	7133	0	2	3	33	0	-1	42
SB La Canada	7134	0	0	0	1	0	0	45
SB La Canada	7135	1	1	0	3	0	1	43
SB La Canada	7136	0	1	1	5	0	0	43
SB La Canada	7137	0	2	2	10	0	0	41
SB La Canada	7138	0	3	3	20	0	0	39
SB La Canada	7139	0	4	3	27	0	1	37
SB La Canada	7140	1	5	3	27	0	2	35
SB La Canada	7141	0	5	6	36	0	-1	35
SB La Canada	7142	0	0	0	-4	0	0	43
SB La Canada	7143	0	1	1	2	0	0	41
SB La Canada	7144	0	2	1	7	0	1	39
SB La Canada	7145	1	3	0	9	0	3	37
SB La Canada	7146	1	3	1	14	0	2	37
SB La Canada	7147	0	3	2	16	0	1	37
SB La Canada	7148	0	4	2	19	0	2	35
SB La Canada	7149	0	2	0	26	0	2	39
SB La Canada	7150	0	0	0	-1	0	0	40
SB La Canada	7151	0	1	0	3	0	1	38
SB La Canada	7152	0	2	0	5	0	2	36
SB La Canada	7153	0	3	0	6	0	3	34
SB La Canada	7154	0	4	0	9	0	4	32
SB La Canada	7155	1	5	0	9	0	5	30
SB La Canada	7156	1	5	2	15	0	3	30
SB La Canada	7157	0	5	3	19	0	2	30
SB La Canada	7158	0	6	4	20	0	2	28
SB La Canada	7159	0	7	4	23	0	3	26
SB La Canada	7160	0	8	4	41	0	4	24
SB La Canada	7161	0	0	0	-4	0	0	49
SB La Canada	7162	0	1	0	-1	0	1	47
SB La Canada	7163	0	2	0	1	0	2	45
SB La Canada	7164	0	3	0	6	0	3	43
SB La Canada	7165	0	4	0	10	0	4	41
SB La Canada	7166	0	5	1	22	0	4	39
SB La Canada	7167	0	6	0	33	0	6	37
SB La Canada	7168	0	0	0	3	0	0	44
SB La Canada	7169	0	1	0	6	0	1	42

SB La Canada	7170	0	2	0	8	0	2	40
SB La Canada	7171	1	3	0	8	0	3	38
SB La Canada	7172	0	3	1	10	0	2	38
SB La Canada	7173	1	4	1	10	0	3	36
SB La Canada	7174	1	4	2	28	0	2	36
SB La Canada	7175	0	0	1	0	0	-1	36
SB La Canada	7176	0	1	0	8	0	1	34
SB La Canada	7177	1	2	0	22	0	2	32
SB La Canada	7178	0	2	1	26	0	1	32
SB La Canada	7179	0	3	1	28	0	2	30
SB La Canada	7180	0	4	1	30	0	3	28
SB La Canada	7181	0	5	2	32	0	3	26
SB La Canada	7182	0	6	2	34	0	4	24
SB La Canada	7183	0	7	2	36	0	5	22
SB La Canada	7184	0	8	2	38	0	6	20
SB La Canada	7185	1	9	3	40	0	6	18
SB La Canada	7186	0	0	0	-3	0	0	39
SB La Canada	7187	0	1	2	8	0	-1	37
SB La Canada	7188	1	2	2	13	0	0	35
SB La Canada	7189	0	2	1	34	0	1	35
SB La Canada	7190	0	3	1	46	0	2	33
SB La Canada	7191	0	0	0	-2	0	0	36
SB La Canada	7192	1	1	0	-2	0	1	34
SB La Canada	7193	0	1	1	-1	0	0	34
SB La Canada	7194	1	2	1	-1	0	1	32
SB La Canada	7195	1	2	2	4	0	0	32
SB La Canada	7196	0	2	4	8	0	-2	32
SB La Canada	7197	0	3	4	9	0	-1	30
SB La Canada	7198	0	4	5	18	0	-1	28
SB La Canada	7199	0	5	5	22	0	0	26
SB La Canada	7200	0	6	5	23	0	1	24
SB La Canada	7201	1	7	5	35	0	2	22
SB La Canada	7202	0	0	0	-3	0	0	42
SB La Canada	7203	0	1	0	-2	0	1	40
SB La Canada	7204	0	2	0	7	0	2	38
SB La Canada	7205	1	3	0	7	0	3	36
SB La Canada	7206	0	3	2	17	0	1	36
SB La Canada	7207	0	4	2	19	0	2	34
SB La Canada	7208	0	5	2	28	0	3	32
SB La Canada	7209	0	6	2	30	0	4	30

SB La Canada	7210	0	7	2	45	0	5	28
SB La Canada	7211	0	0	1	2	0	-1	33
SB La Canada	7212	1	1	2	6	0	-1	31
SB La Canada	7213	0	1	3	9	0	-2	31
SB La Canada	7214	0	2	3	14	0	-1	29
SB La Canada	7215	1	3	3	14	0	0	27
SB La Canada	7216	1	3	4	22	0	-1	27
SB La Canada	7217	0	0	0	5	0	0	37
SB La Canada	7218	0	1	0	12	0	1	35
SB La Canada	7219	0	2	0	24	0	2	33
SB La Canada	7220	1	3	0	24	0	3	31
SB La Canada	7221	0	3	1	33	0	2	31
SB La Canada	7222	0	0	1	-3	0	-1	39
SB La Canada	7223	1	1	1	-2	0	0	37
SB La Canada	7224	0	1	2	0	0	-1	37
SB La Canada	7225	0	2	2	2	0	0	35
SB La Canada	7226	0	3	1	7	0	2	33
SB La Canada	7227	0	4	1	11	0	3	31
SB La Canada	7228	1	5	1	21	0	4	29
SB La Canada	7229	0	5	2	22	0	3	29
SB La Canada	7230	0	6	2	29	0	4	27
SB La Canada	7231	0	7	2	32	0	5	25
SB La Canada	7232	0	8	2	41	0	6	23
SB La Canada	7233	0	9	2	45	0	7	21
SB La Canada	7234	0	0	0	-3	0	0	36
SB La Canada	7235	0	1	0	-2	0	1	34
SB La Canada	7236	0	2	0	2	0	2	32
SB La Canada	7237	1	3	0	4	0	3	30
SB La Canada	7238	0	3	1	8	0	2	30
SB La Canada	7239	1	4	2	10	0	2	28
SB La Canada	7240	1	5	1	13	0	4	26
SB La Canada	7241	0	4	3	24	0	1	28
SB La Canada	7242	0	0	0	-3	0	0	39
SB La Canada	7243	0	1	0	-1	0	1	37
SB La Canada	7244	0	2	0	3	0	2	35
SB La Canada	7245	0	3	0	6	0	3	33
SB La Canada	7246	1	4	1	10	0	3	31
SB La Canada	7247	1	4	2	17	0	2	31
SB La Canada	7248	0	4	3	17	0	1	31
SB La Canada	7249	0	5	2	21	0	3	29

SB La Canada	7250	0	6	2	23	0	4	27
SB La Canada	7251	0	7	2	27	0	5	25
SB La Canada	7252	0	8	2	29	0	6	23
SB La Canada	7253	1	9	2	29	0	7	21
SB La Canada	7254	0	0	0	-4	0	0	37
SB La Canada	7255	0	1	2	2	0	-1	35
SB La Canada	7256	1	2	2	5	0	0	33
SB La Canada	7257	0	2	2	10	0	0	33
SB La Canada	7258	1	3	2	12	0	1	31
SB La Canada	7259	0	3	2	23	0	1	31
SB La Canada	7260	0	4	2	24	0	2	29
SB La Canada	7261	0	5	2	26	0	3	27
SB La Canada	7262	0	6	2	28	0	4	25
SB La Canada	7263	0	7	2	31	0	5	23
SB La Canada	7264	0	0	0	-4	0	0	41
SB La Canada	7265	0	1	1	0	0	0	39
SB La Canada	7266	1	2	1	10	0	1	37
SB La Canada	7267	0	2	2	13	0	0	37
SB La Canada	7268	0	3	2	14	0	1	35
SB La Canada	7269	0	4	2	18	0	2	33
SB La Canada	7270	1	5	2	18	0	3	31
SB La Canada	7271	0	5	2	20	0	3	31
SB La Canada	7272	0	6	2	22	0	4	29
SB La Canada	7273	0	7	2	26	0	5	27
SB La Canada	7274	0	8	2	27	0	6	25
SB La Canada	7275	1	9	2	29	0	7	23
SB La Canada	7276	0	9	3	31	0	6	23
SB La Canada	7277	0	10	3	37	0	7	21
SB La Canada	7278	0	10	6	47	0	4	21
SB La Canada	7279	0	0	0	3	0	0	36
SB La Canada	7280	0	1	0	4	0	1	34
SB La Canada	7281	0	2	2	12	0	0	32
SB La Canada	7282	0	3	2	14	0	1	30
SB La Canada	7283	1	4	1	22	0	3	28
SB La Canada	7284	0	0	0	-5	0	0	35
SB La Canada	7285	0	1	1	0	0	0	33
SB La Canada	7286	1	2	1	5	0	1	31
SB La Canada	7287	0	2	2	9	0	0	31
SB La Canada	7288	0	3	2	11	0	1	29
SB La Canada	7289	1	4	2	14	0	2	27

SB La Canada	7290	0	4	3	16	0	1	27
SB La Canada	7291	1	5	3	18	0	2	25
SB La Canada	7292	0	5	4	19	0	1	25
SB La Canada	7293	0	0	1	8	0	-1	40
SB La Canada	7294	0	1	1	17	0	0	38
SB La Canada	7295	1	2	1	24	0	1	36
SB La Canada	7296	0	2	2	27	0	0	36
SB La Canada	7297	0	3	2	48	0	1	34
SB La Canada	7298	0	9	4	0	44	0	26
SB La Canada	7299	1	0	2	0	12	0	12
SB La Canada	7300	0	3	0	0	62	0	56
SB La Canada	7301	0	2	0	0	58	0	54
SB La Canada	7302	0	2	1	0	57	0	53
SB La Canada	7303	0	3	0	0	57	0	51
SB La Canada	7304	0	6	3	0	63	0	51
SB La Canada	7305	1	7	2	0	64	0	50
SB La Canada	7306	1	3	2	0	55	0	49
SB La Canada	7307	1	3	3	0	54	0	48
SB La Canada	7308	0	3	4	0	53	0	47
SB La Canada	7309	0	3	2	0	52	0	46
SB La Canada	7310	0	3	1	0	49	0	43
SB La Canada	7311	1	4	2	0	50	0	42
SB La Canada	7312	1	2	2	0	46	0	42
SB La Canada	7313	0	0	0	0	42	0	42
SB La Canada	7314	1	1	0	0	44	0	42
SB La Canada	7315	0	0	1	0	41	0	41
SB La Canada	7316	0	0	0	0	40	0	40
SB La Canada	7317	0	3	1	0	46	0	40
SB La Canada	7318	1	7	3	0	53	0	39
SB La Canada	7319	1	5	0	0	49	0	39
SB La Canada	7320	0	2	3	0	43	0	39
SB La Canada	7321	0	0	0	0	38	0	38
SB La Canada	7322	0	3	1	0	44	0	38
SB La Canada	7323	0	1	2	0	39	0	37
SB La Canada	7324	0	1	0	0	38	0	36
SB La Canada	7325	0	3	0	0	42	0	36
SB La Canada	7326	1	3	2	0	42	0	36
SB La Canada	7327	0	1	1	0	38	0	36
SB La Canada	7328	0	2	1	0	39	0	35
SB La Canada	7329	0	5	2	0	45	0	35

SB La Canada	7330	0	0	0	0	34	0	34
SB La Canada	7331	0	1	0	0	36	0	34
SB La Canada	7332	0	0	0	0	34	0	34
SB La Canada	7333	0	0	0	0	34	0	34
SB La Canada	7334	0	2	1	0	38	0	34
SB La Canada	7335	0	0	0	0	34	0	34
SB La Canada	7336	0	1	0	0	34	0	32
SB La Canada	7337	0	3	0	0	38	0	32
SB La Canada	7338	1	0	0	0	32	0	32
SB La Canada	7339	0	0	0	0	32	0	32
SB La Canada	7340	0	0	1	0	32	0	32
SB La Canada	7341	0	0	0	0	31	0	31
SB La Canada	7342	0	0	0	0	31	0	31
SB La Canada	7343	0	3	2	0	37	0	31
SB La Canada	7344	1	5	0	0	41	0	31
SB La Canada	7345	0	2	1	0	35	0	31
SB La Canada	7346	0	1	1	0	32	0	30
SB La Canada	7347	0	0	0	0	30	0	30
SB La Canada	7348	1	1	0	0	32	0	30
SB La Canada	7349	1	5	1	0	40	0	30
SB La Canada	7350	1	2	1	0	34	0	30
SB La Canada	7351	0	0	0	0	30	0	30
SB La Canada	7352	0	2	0	0	34	0	30
SB La Canada	7353	0	4	2	0	38	0	30
SB La Canada	7354	0	3	2	0	35	0	29
SB La Canada	7355	0	0	0	0	29	0	29
SB La Canada	7356	0	0	0	0	29	0	29
SB La Canada	7357	0	4	0	0	37	0	29
SB La Canada	7358	0	6	6	0	41	0	29
SB La Canada	7359	0	1	1	0	31	0	29
SB La Canada	7360	0	1	1	0	31	0	29
SB La Canada	7361	0	0	0	0	29	0	29
SB La Canada	7362	0	1	0	0	30	0	28
SB La Canada	7363	0	0	0	0	28	0	28
SB La Canada	7364	0	0	1	0	28	0	28
SB La Canada	7365	0	0	1	0	28	0	28
SB La Canada	7366	1	4	1	0	36	0	28
SB La Canada	7367	0	2	2	0	32	0	28
SB La Canada	7368	0	4	1	0	36	0	28
SB La Canada	7369	1	3	1	0	34	0	28

SB La Canada	7370	1	1	1	0	30	0	28
SB La Canada	7371	0	0	1	0	28	0	28
SB La Canada	7372	0	3	2	0	34	0	28
SB La Canada	7373	0	0	0	0	27	0	27
SB La Canada	7374	0	1	0	0	29	0	27
SB La Canada	7375	1	0	0	0	27	0	27
SB La Canada	7376	0	1	0	0	29	0	27
SB La Canada	7377	1	5	1	0	37	0	27
SB La Canada	7378	0	4	2	0	35	0	27
SB La Canada	7379	0	0	1	0	27	0	27
SB La Canada	7380	0	2	0	0	31	0	27
SB La Canada	7381	1	5	0	0	37	0	27
SB La Canada	7382	0	1	0	0	29	0	27
SB La Canada	7383	0	3	3	0	33	0	27
SB La Canada	7384	1	2	1	0	31	0	27
SB La Canada	7385	0	1	0	0	28	0	26
SB La Canada	7386	0	0	0	0	26	0	26
SB La Canada	7387	0	1	0	0	28	0	26
SB La Canada	7388	0	1	0	0	28	0	26
SB La Canada	7389	0	0	0	0	26	0	26
SB La Canada	7390	1	7	2	0	40	0	26
SB La Canada	7391	0	0	0	0	26	0	26
SB La Canada	7392	0	0	0	0	25	0	25
SB La Canada	7393	0	0	0	0	25	0	25
SB La Canada	7394	0	0	0	0	25	0	25
SB La Canada	7395	0	8	11	0	41	0	25
SB La Canada	7396	0	0	0	0	25	0	25
SB La Canada	7397	0	1	0	0	27	0	25
SB La Canada	7398	0	0	0	0	25	0	25
SB La Canada	7399	0	1	2	0	27	0	25
SB La Canada	7400	0	1	1	0	27	0	25
SB La Canada	7401	0	0	1	0	25	0	25
SB La Canada	7402	0	3	2	0	31	0	25
SB La Canada	7403	1	2	0	0	28	0	24
SB La Canada	7404	0	0	1	0	24	0	24
SB La Canada	7405	0	0	1	0	24	0	24
SB La Canada	7406	1	1	0	0	26	0	24
SB La Canada	7407	1	3	0	0	30	0	24
SB La Canada	7408	0	0	1	0	24	0	24
SB La Canada	7409	0	3	3	0	30	0	24

SB La Canada	7410	0	2	1	0	28	0	24
SB La Canada	7411	0	2	2	0	28	0	24
SB La Canada	7412	0	1	0	0	26	0	24
SB La Canada	7413	0	1	1	0	25	0	23
SB La Canada	7414	0	0	0	0	23	0	23
SB La Canada	7415	0	0	0	0	23	0	23
SB La Canada	7416	0	1	0	0	25	0	23
SB La Canada	7417	0	2	1	0	27	0	23
SB La Canada	7418	1	2	1	0	27	0	23
SB La Canada	7419	0	2	0	0	27	0	23
SB La Canada	7420	0	1	0	0	24	0	22
SB La Canada	7421	0	1	0	0	24	0	22
SB La Canada	7422	0	1	0	0	24	0	22
SB La Canada	7423	0	1	0	0	24	0	22
SB La Canada	7424	0	1	1	0	24	0	22
SB La Canada	7425	0	0	0	0	22	0	22
SB La Canada	7426	0	6	0	0	34	0	22
SB La Canada	7427	1	1	0	0	24	0	22
SB La Canada	7428	0	1	1	0	24	0	22
SB La Canada	7429	0	1	1	0	24	0	22
SB La Canada	7430	1	3	1	0	28	0	22
SB La Canada	7431	0	1	0	0	23	0	21
SB La Canada	7432	0	1	0	0	23	0	21
SB La Canada	7433	0	1	1	0	23	0	21
SB La Canada	7434	0	1	0	0	23	0	21
SB La Canada	7435	1	2	0	0	25	0	21
SB La Canada	7436	0	2	0	0	25	0	21
SB La Canada	7437	0	1	1	0	23	0	21
SB La Canada	7438	0	2	0	0	25	0	21
SB La Canada	7439	1	5	0	0	30	0	20
SB La Canada	7440	0	1	0	0	22	0	20
SB La Canada	7441	0	0	1	0	20	0	20
SB La Canada	7442	0	2	0	0	24	0	20
SB La Canada	7443	0	1	2	0	22	0	20
SB La Canada	7444	0	0	0	0	20	0	20
SB La Canada	7445	0	1	1	0	22	0	20
SB La Canada	7446	0	0	0	0	20	0	20
SB La Canada	7447	0	1	1	0	22	0	20
SB La Canada	7448	0	1	1	0	22	0	20
SB La Canada	7449	0	1	0	0	22	0	20

SB La Canada	7450	0	2	0	0	24	0	20
SB La Canada	7451	0	0	0	0	20	0	20
SB La Canada	7452	0	0	1	0	20	0	20
SB La Canada	7453	0	2	1	0	24	0	20
SB La Canada	7454	0	1	0	0	21	0	19
SB La Canada	7455	0	0	1	0	19	0	19
SB La Canada	7456	0	1	0	0	21	0	19
SB La Canada	7457	0	7	0	0	33	0	19
SB La Canada	7458	0	2	0	0	23	0	19
SB La Canada	7459	1	5	1	0	28	0	18
SB La Canada	7460	0	0	1	0	18	0	18
SB La Canada	7461	0	2	0	0	22	0	18
SB La Canada	7462	0	0	0	0	18	0	18
SB La Canada	7463	0	0	1	0	18	0	18
SB La Canada	7464	0	2	0	0	21	0	17
SB La Canada	7465	0	1	0	0	19	0	17
SB La Canada	7466	1	8	0	0	33	0	17
SB La Canada	7467	0	1	2	0	19	0	17
SB La Canada	7468	0	2	1	0	21	0	17
SB La Canada	7469	0	1	0	0	19	0	17
SB La Canada	7470	0	2	1	0	21	0	17
SB La Canada	7471	1	0	0	0	17	0	17
SB La Canada	7472	0	2	1	0	21	0	17
SB La Canada	7473	0	1	0	0	19	0	17
SB La Canada	7474	0	2	0	0	21	0	17
SB La Canada	7475	0	2	0	0	21	0	17
SB La Canada	7476	0	2	0	0	21	0	17
SB La Canada	7477	0	0	0	0	16	0	16
SB La Canada	7478	0	2	0	0	20	0	16
SB La Canada	7479	0	1	1	0	18	0	16
SB La Canada	7480	0	1	0	0	18	0	16
SB La Canada	7481	0	3	0	0	22	0	16
SB La Canada	7482	0	1	1	0	18	0	16
SB La Canada	7483	0	5	2	0	26	0	16
SB La Canada	7484	0	2	1	0	20	0	16
SB La Canada	7485	0	1	0	0	18	0	16
SB La Canada	7486	0	1	2	0	18	0	16
SB La Canada	7487	0	1	2	0	18	0	16
SB La Canada	7488	0	2	0	0	19	0	15
SB La Canada	7489	0	2	0	0	19	0	15

SB La Canada	7490	0	0	0	0	15	0	15
SB La Canada	7491	0	2	1	0	19	0	15
SB La Canada	7492	1	0	0	0	15	0	15
SB La Canada	7493	0	1	0	0	17	0	15
SB La Canada	7494	0	3	3	0	21	0	15
SB La Canada	7495	0	4	0	0	22	0	14
SB La Canada	7496	0	2	0	0	18	0	14
SB La Canada	7497	1	1	0	0	16	0	14
SB La Canada	7498	0	5	1	0	24	0	14
SB La Canada	7499	0	2	0	0	18	0	14
SB La Canada	7500	0	1	0	0	16	0	14
SB La Canada	7501	1	6	2	0	26	0	14
SB La Canada	7502	1	2	2	0	18	0	14
SB La Canada	7503	0	1	1	0	16	0	14
SB La Canada	7504	0	3	0	0	20	0	14
SB La Canada	7505	1	1	0	0	15	0	13
SB La Canada	7506	0	1	1	0	15	0	13
SB La Canada	7507	0	2	0	0	17	0	13
SB La Canada	7508	0	1	1	0	15	0	13
SB La Canada	7509	0	2	0	0	17	0	13
SB La Canada	7510	0	2	2	0	17	0	13
SB La Canada	7511	0	1	0	0	15	0	13
SB La Canada	7512	0	2	0	0	17	0	13
SB La Canada	7513	0	2	0	0	17	0	13
SB La Canada	7514	0	2	0	0	17	0	13
SB La Canada	7515	0	1	0	0	15	0	13
SB La Canada	7516	0	3	0	0	19	0	13
SB La Canada	7517	1	1	1	0	14	0	12
SB La Canada	7518	0	3	0	0	18	0	12
SB La Canada	7519	0	0	1	0	12	0	12
SB La Canada	7520	0	0	0	0	12	0	12
SB La Canada	7521	1	2	0	0	16	0	12
SB La Canada	7522	0	2	1	0	16	0	12
SB La Canada	7523	0	1	2	0	14	0	12
SB La Canada	7524	0	2	2	0	16	0	12
SB La Canada	7525	0	1	0	0	14	0	12
SB La Canada	7526	0	1	0	0	14	0	12
SB La Canada	7527	0	0	0	0	12	0	12
SB La Canada	7528	0	1	1	0	14	0	12
SB La Canada	7529	0	0	1	0	12	0	12

SB La Canada	7530	0	0	0	0	12	0	12
SB La Canada	7531	0	2	2	0	16	0	12
SB La Canada	7532	0	0	2	0	12	0	12
SB La Canada	7533	0	3	0	0	18	0	12
SB La Canada	7534	1	0	0	0	12	0	12
SB La Canada	7535	0	1	2	0	13	0	11
SB La Canada	7536	0	0	2	0	11	0	11
SB La Canada	7537	0	0	0	0	11	0	11
SB La Canada	7538	0	0	1	0	11	0	11
SB La Canada	7539	0	3	0	0	16	0	10
SB La Canada	7540	0	0	0	0	10	0	10
SB La Canada	7541	1	1	1	0	12	0	10
SB La Canada	7542	0	2	0	0	14	0	10
SB La Canada	7543	0	0	0	0	10	0	10
SB La Canada	7544	0	1	0	0	12	0	10
SB La Canada	7545	0	0	1	0	10	0	10
SB La Canada	7546	0	2	0	0	14	0	10
SB La Canada	7547	0	2	1	0	14	0	10
SB La Canada	7548	0	0	0	0	10	0	10
SB La Canada	7549	0	1	0	0	12	0	10
SB La Canada	7550	0	0	2	0	10	0	10
SB La Canada	7551	1	1	0	0	11	0	9
SB La Canada	7552	0	1	0	0	11	0	9
SB La Canada	7553	0	2	1	0	13	0	9
SB La Canada	7554	0	2	1	0	13	0	9
SB La Canada	7555	0	0	0	0	9	0	9
SB La Canada	7556	0	0	1	0	9	0	9
SB La Canada	7557	0	2	0	0	13	0	9
SB La Canada	7558	0	1	0	0	11	0	9
SB La Canada	7559	0	1	0	0	11	0	9
SB La Canada	7560	0	1	1	0	11	0	9
SB La Canada	7561	0	2	1	0	13	0	9
SB La Canada	7562	0	1	1	0	10	0	8
SB La Canada	7563	0	3	0	0	14	0	8
SB La Canada	7564	0	2	0	0	12	0	8
SB La Canada	7565	0	0	0	0	8	0	8
SB La Canada	7566	0	1	0	0	10	0	8
SB La Canada	7567	0	1	1	0	10	0	8
SB La Canada	7568	0	2	0	0	11	0	7
SB La Canada	7569	0	0	0	0	7	0	7

SB La Canada	7570	0	1	0	0	9	0	7
SB La Canada	7571	0	0	2	0	7	0	7
SB La Canada	7572	0	0	1	0	7	0	7
SB La Canada	7573	0	0	1	0	7	0	7
SB La Canada	7574	1	0	0	0	7	0	7
SB La Canada	7575	0	1	2	0	9	0	7
SB La Canada	7576	0	0	1	0	6	0	6
SB La Canada	7577	0	1	1	0	8	0	6
SB La Canada	7578	0	2	1	0	10	0	6
SB La Canada	7579	0	3	1	0	12	0	6
SB La Canada	7580	0	2	0	0	10	0	6
SB La Canada	7581	0	0	0	0	6	0	6
SB La Canada	7582	0	2	0	0	10	0	6
SB La Canada	7583	0	1	0	0	8	0	6
SB La Canada	7584	0	1	0	0	8	0	6
SB La Canada	7585	1	1	1	0	8	0	6
SB La Canada	7586	0	0	0	0	6	0	6
SB La Canada	7587	0	2	1	0	9	0	5
SB La Canada	7588	0	1	1	0	7	0	5
SB La Canada	7589	0	2	1	0	9	0	5
SB La Canada	7590	0	2	1	0	9	0	5
SB La Canada	7591	0	1	0	0	7	0	5
SB La Canada	7592	0	1	0	0	7	0	5
SB La Canada	7593	0	2	0	0	9	0	5
SB La Canada	7594	0	2	0	0	8	0	4
SB La Canada	7595	0	2	1	0	8	0	4
SB La Canada	7596	0	1	0	0	6	0	4
SB La Canada	7597	1	2	2	0	8	0	4
SB La Canada	7598	0	1	1	0	5	0	3
SB La Canada	7599	1	1	1	0	5	0	3
SB La Canada	7600	0	2	0	0	7	0	3
SB La Canada	7601	1	2	0	0	7	0	3
SB La Canada	7602	0	2	1	0	7	0	3
SB La Canada	7603	0	1	2	0	5	0	3
SB La Canada	7604	0	2	2	0	7	0	3
SB La Canada	7605	0	2	2	0	7	0	3
SB La Canada	7606	0	3	0	0	8	0	2
SB La Canada	7607	0	2	1	0	5	0	1
SB La Canada	7608	0	3	1	0	7	0	1
SB La Canada	7609	0	2	1	0	5	0	1

EB Walker at 185	8001	1	2	0	0	16	0	21
EB Walker at 185	8002	1	2	1	0	12	0	17
EB Walker at 185	8003	1	5	2	0	12	0	18
EB Walker at 185	8004	1	5	3	0	9	0	15
EB Walker at 185	8005	0	1	0	0	14	0	19
EB Walker at 185	8006	0	1	0	0	12	0	17
EB Walker at 185	8007	0	1	0	0	8	0	13
EB Walker at 185	8008	0	0	0	0	8	0	22
EB Walker at 185	8009	0	5	1	0	10	0	16
EB Walker at 185	8010	1	4	0	0	17	0	13
EB Walker at 185	8011	1	3	1	0	14	0	12
EB Walker at 185	8012	0	1	2	0	11	0	13
EB Walker at 185	8013	0	2	1	0	10	0	10
EB Walker at 185	8014	0	1	0	0	7	0	9
EB Walker at 185	8015	0	3	4	0	14	0	19
EB Walker at 185	8016	1	4	4	0	12	0	15
EB Walker at 185	8017	1	4	5	0	9	0	12
EB Walker at 185	8018	1	6	3	0	19	0	16
EB Walker at 185	8019	0	6	4	0	15	0	12
EB Walker at 185	8020	0	7	4	0	13	0	8
EB Walker at 185	8021	0	0	0	0	8	0	3
EB Walker at 185	8022	0	6	3	0	41	0	15
EB Walker at 185	8023	1	2	0	0	32	0	14
EB Walker at 185	8024	0	0	0	0	8	0	4
EB Walker at 185	8025	0	2	1	0	9	0	17
EB Walker at 185	8026	0	3	5	0	14	0	20
EB Walker at 185	8027	0	2	1	0	11	0	19
EB Walker at 185	8028	0	1	0	0	10	0	20

EB Walker at 185	8029	1	2	0	0	10	0	18
EB Walker at 185	8030	0	7	5	0	18	0	15
EB Walker at 185	8031	1	8	5	0	17	0	12
EB Walker at 185	8032	0	2	1	0	11	0	17
EB Walker at 185	8033	1	1	1	0	10	0	18
EB Walker at 185	8034	0	1	1	0	8	0	16
EB Walker at 185	8035	0	2	0	0	10	0	16
EB Walker at 185	8036	1	5	0	0	12	0	4
EB Walker at 185	8037	1	4	2	0	27	0	17
EB Walker at 185	8038	0	1	0	0	23	0	19
EB Walker at 185	8039	0	0	0	0	11	0	5
EB Walker at 185	8040	1	2	0	0	26	0	20
EB Walker at 185	8041	1	0	0	0	21	0	19
EB Walker at 185	8042	0	0	0	0	17	0	15
EB Walker at 185	8043	0	0	0	0	7	0	5
EB Walker at 185	8044	0	6	5	0	17	0	9
EB Walker at 185	8045	0	7	5	0	15	0	5
EB Walker at 185	8046	1	5	3	0	15	0	9
EB Walker at 185	8047	0	3	1	0	9	0	7
EB Walker at 185	8048	0	4	1	0	7	0	3
EB Walker at 185	8049	1	5	1	0	7	0	1
EB Walker at 185	8050	1	3	2	0	15	0	19
EB Walker at 185	8051	0	2	0	0	7	0	13
EB Walker at 185	8052	0	1	0	0	29	0	20
EB Walker at 185	8053	0	0	0	0	25	0	18
EB Walker at 185	8054	1	1	0	0	25	0	16
EB Walker at 185	8055	0	1	0	0	9	0	14
EB Walker at 185	8056	1	3	1	0	17	0	23

EB Walker at 185	8057	0	0	0	0	11	0	23
EB Walker at 185	8058	0	1	0	0	9	0	19
EB Walker at 185	8059	0	0	0	3	0	0	31
EB Walker at 185	8060	1	1	0	3	0	1	29
EB Walker at 185	8061	0	1	1	27	0	0	29
EB Walker at 185	8062	0	2	1	44	0	1	27
EB Walker at 185	8063	0	3	1	72	0	2	25
EB Walker at 185	8064	0	4	1	92	0	3	23
EB Walker at 185	8065	0	0	0	5	0	0	31
EB Walker at 185	8066	1	1	0	9	0	1	29
EB Walker at 185	8067	0	1	1	53	0	0	29
EB Walker at 185	8068	0	2	1	64	0	1	27
EB Walker at 185	8069	1	3	1	64	0	2	25
EB Walker at 185	8070	1	3	2	67	0	1	25
EB Walker at 185	8071	0	3	3	82	0	0	25
EB Walker at 185	8072	0	4	3	93	0	1	23
EB Walker at 185	8073	1	5	3	93	0	2	21
EB Walker at 185	8074	0	0	0	11	0	0	31
EB Walker at 185	8075	0	1	0	13	0	1	29
EB Walker at 185	8076	1	2	0	20	0	2	27
EB Walker at 185	8077	0	2	1	33	0	1	27
EB Walker at 185	8078	1	3	1	48	0	2	25
EB Walker at 185	8079	0	3	2	84	0	1	25
EB Walker at 185	8080	0	4	2	89	0	2	23
EB Walker at 185	8081	0	0	0	26	0	0	31
EB Walker at 185	8082	0	1	0	28	0	1	29
EB Walker at 185	8083	1	2	0	39	0	2	27
EB Walker at 185	8084	1	2	1	59	0	1	27

EB Walker at 185	8085	0	2	2	70	0	0	27
EB Walker at 185	8086	0	3	2	80	0	1	25
EB Walker at 185	8087	1	0	0	0	0	0	31
EB Walker at 185	8088	0	0	1	49	0	-1	31
EB Walker at 185	8089	0	1	1	56	0	0	29
EB Walker at 185	8090	0	2	1	75	0	1	27
EB Walker at 185	8091	0	3	1	85	0	2	25
EB Walker at 185	8092	0	0	0	19	0	0	31
EB Walker at 185	8093	1	1	0	19	0	1	29
EB Walker at 185	8094	0	1	1	35	0	0	29
EB Walker at 185	8095	1	2	1	38	0	1	27
EB Walker at 185	8096	1	2	2	45	0	0	27
EB Walker at 185	8097	1	0	0	65	0	0	31
EB Walker at 185	8098	0	0	1	78	0	-1	31
EB Walker at 185	8099	0	1	1	85	0	0	29
EB Walker at 185	8100	0	2	1	89	0	1	27
EB Walker at 185	8101	0	3	1	93	0	2	25
EB Walker at 185	8102	0	4	1	96	0	3	23
EB Walker at 185	8103	1	2	0	33	0	2	27
EB Walker at 185	8104	0	2	1	44	0	1	27
EB Walker at 185	8105	1	3	1	51	0	2	25
EB Walker at 185	8106	0	3	2	56	0	1	25
EB Walker at 185	8107	0	4	2	65	0	2	23
EB Walker at 185	8108	1	5	2	71	0	3	21
EB Walker at 185	8109	0	5	3	89	0	2	21
EB Walker at 185	8110	0	6	3	102	0	3	19
EB Walker at 185	8111	0	0	0	18	0	0	31
EB Walker at 185	8112	1	1	0	24	0	1	29

EB Walker at 185	8113	0	1	1	30	0	0	29
EB Walker at 185	8114	0	2	1	32	0	1	27
EB Walker at 185	8115	1	3	1	41	0	2	25
EB Walker at 185	8116	1	3	2	54	0	1	25
EB Walker at 185	8117	1	3	3	58	0	0	25
EB Walker at 185	8118	0	0	0	26	0	0	31
EB Walker at 185	8119	0	1	0	28	0	1	29
EB Walker at 185	8120	1	2	0	33	0	2	27
EB Walker at 185	8121	0	2	1	38	0	1	27
EB Walker at 185	8122	0	3	1	43	0	2	25
EB Walker at 185	8123	0	4	1	55	0	3	23
EB Walker at 185	8124	1	5	1	58	0	4	21
EB Walker at 185	8125	0	5	2	97	0	3	21
EB Walker at 185	8126	1	6	2	97	0	4	19
EB Walker at 185	8127	0	0	0	20	0	0	31
EB Walker at 185	8128	1	1	0	20	0	1	29
EB Walker at 185	8129	0	1	1	23	0	0	29
EB Walker at 185	8130	0	2	1	30	0	1	27
EB Walker at 185	8131	0	3	1	34	0	2	25
EB Walker at 185	8132	1	4	1	42	0	3	23
EB Walker at 185	8133	0	4	2	57	0	2	23
EB Walker at 185	8134	1	5	2	57	0	3	21
EB Walker at 185	8135	0	0	0	1	0	0	31
EB Walker at 185	8136	1	1	0	1	0	1	29
EB Walker at 185	8137	0	1	1	4	0	0	29
EB Walker at 185	8138	0	2	1	38	0	1	27
EB Walker at 185	8139	0	3	1	41	0	2	25
EB Walker at 185	8140	1	4	1	42	0	3	23

EB Walker at 185	8141	0	4	2	60	0	2	23
EB Walker at 185	8142	0	5	2	77	0	3	21
EB Walker at 185	8143	1	6	2	77	0	4	19
EB Walker at 185	8144	0	0	0	-3	0	0	31
EB Walker at 185	8145	1	1	0	11	0	1	29
EB Walker at 185	8146	0	1	1	23	0	0	29
EB Walker at 185	8147	0	2	1	31	0	1	27
EB Walker at 185	8148	0	3	1	33	0	2	25
EB Walker at 185	8149	0	4	1	37	0	3	23
EB Walker at 185	8150	1	5	1	48	0	4	21
EB Walker at 185	8151	0	5	2	60	0	3	21
EB Walker at 185	8152	0	6	2	64	0	4	19
EB Walker at 185	8153	0	0	0	38	0	0	31
EB Walker at 185	8154	1	1	0	38	0	1	29
EB Walker at 185	8155	1	1	1	69	0	0	29
EB Walker at 185	8156	0	0	0	25	0	0	31
EB Walker at 185	8157	0	1	0	27	0	1	29
EB Walker at 185	8158	0	2	0	58	0	2	27
EB Walker at 185	8159	1	3	0	66	0	3	25
EB Walker at 185	8160	0	3	1	69	0	2	25
EB Walker at 185	8161	1	4	1	74	0	3	23
EB Walker at 185	8162	0	4	2	78	0	2	23
EB Walker at 185	8163	1	5	2	101	0	3	21
EB Walker at 185	8164	1	5	3	103	0	2	21
EB Walker at 185	8165	0	0	0	0	0	0	31
EB Walker at 185	8166	1	1	0	0	0	1	29
EB Walker at 185	8167	0	1	1	12	0	0	29
EB Walker at 185	8168	1	2	1	14	0	1	27

EB Walker at 185	8169	1	2	2	43	0	0	27
EB Walker at 185	8170	0	2	3	50	0	-1	27
EB Walker at 185	8171	1	3	3	55	0	0	25
EB Walker at 185	8172	1	3	4	96	0	-1	25
EB Walker at 185	8173	0	0	0	-1	0	0	31
EB Walker at 185	8174	0	1	0	7	0	1	29
EB Walker at 185	8175	0	2	0	8	0	2	27
EB Walker at 185	8176	0	3	0	36	0	3	25
EB Walker at 185	8177	0	4	0	40	0	4	23
EB Walker at 185	8178	1	5	0	41	0	5	21
EB Walker at 185	8179	1	5	1	52	0	4	21
EB Walker at 185	8180	0	5	2	57	0	3	21
EB Walker at 185	8181	0	6	2	58	0	4	19
EB Walker at 185	8182	1	7	2	58	0	5	17
EB Walker at 185	8183	1	7	3	61	0	4	17
EB Walker at 185	8184	1	7	4	94	0	3	17
EB Walker at 185	8185	0	0	0	9	0	0	31
EB Walker at 185	8186	1	1	0	17	0	1	29
EB Walker at 185	8187	0	1	1	32	0	0	29
EB Walker at 185	8188	0	2	1	34	0	1	27
EB Walker at 185	8189	0	3	1	44	0	2	25
EB Walker at 185	8190	1	4	1	60	0	3	23
EB Walker at 185	8191	1	4	2	65	0	2	23
EB Walker at 185	8192	0	4	3	69	0	1	23
EB Walker at 185	8193	0	5	3	85	0	2	21
EB Walker at 185	8194	0	6	3	94	0	3	19
EB Walker at 185	8195	0	0	0	0	0	0	31
EB Walker at 185	8196	0	1	0	18	0	1	29

EB Walker at 185	8197	1	2	0	18	0	2	27
EB Walker at 185	8198	1	2	1	28	0	1	27
EB Walker at 185	8199	1	2	2	33	0	0	27
EB Walker at 185	8200	0	2	3	36	0	-1	27
EB Walker at 185	8201	1	3	3	36	0	0	25
EB Walker at 185	8202	1	3	4	79	0	-1	25
EB Walker at 185	8203	0	3	5	85	0	-2	25
EB Walker at 185	8204	0	0	0	13	0	0	31
EB Walker at 185	8205	1	1	0	16	0	1	29
EB Walker at 185	8206	1	1	1	44	0	0	29
EB Walker at 185	8207	0	1	2	48	0	-1	29
EB Walker at 185	8208	0	2	2	52	0	0	27
EB Walker at 185	8209	0	3	2	85	0	1	25
EB Walker at 185	8210	0	4	2	93	0	2	23
EB Walker at 185	8211	0	0	0	10	0	0	31
EB Walker at 185	8212	0	1	0	14	0	1	29
EB Walker at 185	8213	0	2	0	18	0	2	27
EB Walker at 185	8214	1	3	0	20	0	3	25
EB Walker at 185	8215	1	3	1	23	0	2	25
EB Walker at 185	8216	0	3	2	32	0	1	25
EB Walker at 185	8217	0	4	2	50	0	2	23
EB Walker at 185	8218	1	5	2	52	0	3	21
EB Walker at 185	8219	1	5	3	55	0	2	21
EB Walker at 185	8220	1	5	4	58	0	1	21
EB Walker at 185	8221	0	5	5	62	0	0	21
EB Walker at 185	8222	1	6	5	62	0	1	19
EB Walker at 185	8223	0	6	6	68	0	0	19
EB Walker at 185	8224	1	7	6	69	0	1	17

EB Walker at 185	8225	0	7	7	74	0	0	17
EB Walker at 185	8226	0	8	7	79	0	1	15
EB Walker at 185	8227	0	9	7	81	0	2	13
EB Walker at 185	8228	0	10	7	83	0	3	11
EB Walker at 185	8229	0	11	7	85	0	4	9
EB Walker at 185	8230	1	12	7	92	0	5	7
EB Walker at 185	8231	0	0	0	-1	0	0	31
EB Walker at 185	8232	1	1	0	15	0	1	29
EB Walker at 185	8233	0	1	1	18	0	0	29
EB Walker at 185	8234	1	2	1	64	0	1	27
EB Walker at 185	8235	0	2	2	70	0	0	27
EB Walker at 185	8236	0	3	2	85	0	1	25
EB Walker at 185	8237	0	0	0	25	0	0	31
EB Walker at 185	8238	0	1	0	27	0	1	29
EB Walker at 185	8239	0	2	0	32	0	2	27
EB Walker at 185	8240	0	3	0	46	0	3	25
EB Walker at 185	8241	0	4	0	46	0	4	23
EB Walker at 185	8242	1	5	0	46	0	5	21
EB Walker at 185	8243	1	5	1	47	0	4	21
EB Walker at 185	8244	0	5	2	70	0	3	21
EB Walker at 185	8245	0	0	0	-4	0	0	31
EB Walker at 185	8246	0	1	0	-2	0	1	29
EB Walker at 185	8247	1	2	0	29	0	2	27
EB Walker at 185	8248	0	2	1	41	0	1	27
EB Walker at 185	8249	0	0	0	-3	0	0	31
EB Walker at 185	8250	0	1	0	6	0	1	29
EB Walker at 185	8251	1	2	0	11	0	2	27
EB Walker at 185	8252	1	2	1	16	0	1	27

EB Walker at 185	8253	0	2	2	21	0	0	27
EB Walker at 185	8254	0	3	2	27	0	1	25
EB Walker at 185	8255	1	4	2	27	0	2	23
EB Walker at 185	8256	1	4	3	59	0	1	23
EB Walker at 185	8257	0	4	4	63	0	0	23
EB Walker at 185	8258	0	5	4	66	0	1	21
EB Walker at 185	8259	1	6	4	66	0	2	19
EB Walker at 185	8260	0	0	0	34	0	0	31
EB Walker at 185	8261	0	1	0	36	0	1	29
EB Walker at 185	8262	1	2	0	36	0	2	27
EB Walker at 185	8263	1	2	1	43	0	1	27
EB Walker at 185	8264	1	2	2	58	0	0	27
EB Walker at 185	8265	0	2	3	67	0	-1	27
EB Walker at 185	8266	0	3	3	77	0	0	25
EB Walker at 185	8267	0	0	0	15	0	0	31
EB Walker at 185	8268	1	1	0	26	0	1	29
EB Walker at 185	8269	0	1	1	38	0	0	29
EB Walker at 185	8270	1	2	1	43	0	1	27
EB Walker at 185	8271	1	2	2	46	0	0	27
EB Walker at 185	8272	0	2	3	57	0	-1	27
EB Walker at 185	8273	0	3	3	63	0	0	25
EB Walker at 185	8274	1	4	3	63	0	1	23
EB Walker at 185	8275	0	4	4	84	0	0	23
EB Walker at 185	8276	0	5	4	89	0	1	21
EB Walker at 185	8277	0	1	0	47	0	1	29
EB Walker at 185	8278	0	2	0	56	0	2	27
EB Walker at 185	8279	0	3	0	62	0	3	25
EB Walker at 185	8280	1	4	0	93	0	4	23

EB Walker at 185	8281	0	4	1	105	0	3	23
EB Walker at 185	8282	0	0	0	-3	0	0	31
EB Walker at 185	8283	1	1	0	24	0	1	29
EB Walker at 185	8284	0	1	1	45	0	0	29
EB Walker at 185	8285	1	2	1	52	0	1	27
EB Walker at 185	8286	0	2	2	62	0	0	27
EB Walker at 185	8287	0	3	2	66	0	1	25
EB Walker at 185	8288	0	3	1	79	0	2	25
EB Walker at 185	8289	0	2	0	82	0	2	27
EB Walker at 185	8290	0	1	0	86	0	1	29
EB Walker at 185	8291	0	0	0	4	0	0	31
EB Walker at 185	8292	0	1	0	42	0	1	29
EB Walker at 185	8293	1	2	0	45	0	2	27
EB Walker at 185	8294	0	2	1	51	0	1	27
EB Walker at 185	8295	1	3	1	61	0	2	25
EB Walker at 185	8296	1	3	2	69	0	1	25
EB Walker at 185	8297	0	3	3	76	0	0	25
EB Walker at 185	8298	0	4	3	86	0	1	23
EB Walker at 185	8299	0	5	3	96	0	2	21
EB Walker at 185	8300	0	0	0	5	0	0	31
EB Walker at 185	8301	1	1	0	17	0	1	29
EB Walker at 185	8302	0	1	1	19	0	0	29
EB Walker at 185	8303	0	2	1	82	0	1	27
WB Walker at Murray	9001	1	13	5	0	30	0	5
WB Walker at Murray	9002	0	10	2	0	22	0	3
WB Walker at Murray	9003	0	14	12	0	32	0	2
WB Walker at Murray	9004	0	5	3	0	13	0	2
WB Walker at Murray	9005	0	8	9	0	26	0	15

WB Walker at Murray	9006	0	11	5	0	31	0	7
WB Walker at Murray	9007	0	12	5	0	29	0	3
WB Walker at Murray	9008	1	10	4	0	23	0	1
WB Walker at Murray	9009	0	7	2	0	20	0	4
WB Walker at Murray	9010	0	7	2	0	18	0	2
WB Walker at Murray	9011	0	7	2	0	16	0	0
WB Walker at Murray	9012	1	8	2	0	31	0	13
WB Walker at Murray	9013	0	5	3	0	26	0	14
WB Walker at Murray	9014	0	4	3	0	21	0	11
WB Walker at Murray	9015	0	4	3	0	20	0	10
WB Walker at Murray	9016	0	3	4	0	15	0	7
WB Walker at Murray	9017	1	14	5	0	20	0	-7
WB Walker at Murray	9018	0	11	3	0	16	0	-5
WB Walker at Murray	9019	1	8	2	0	11	0	-4
WB Walker at Murray	9020	0	8	2	0	9	0	-6
WB Walker at Murray	9021	0	20	4	0	32	0	-10
WB Walker at Murray	9022	0	20	3	0	29	0	-13
WB Walker at Murray	9023	1	25	8	0	33	0	-19
WB Walker at Murray	9024	0	26	8	0	31	0	-23
WB Walker at Murray	9025	1	19	17	0	31	0	-7
WB Walker at Murray	9026	0	19	18	0	29	0	-9
WB Walker at Murray	9027	0	21	19	0	20	0	-22
WB Walker at Murray	9028	1	22	19	0	17	0	-27
WB Walker at Murray	9029	0	22	20	0	15	0	-29
WB Walker at Murray	9030	0	23	20	0	8	0	-38
WB Walker at Murray	9031	0	24	20	0	6	0	-42
WB Walker at Murray	9032	0	17	11	0	23	0	-6
WB Walker at Murray	9033	0	18	11	0	20	0	-11

WB Walker at Murray	9034	1	19	12	0	17	0	-16
WB Walker at Murray	9035	1	13	10	0	32	0	4
WB Walker at Murray	9036	0	11	9	0	29	0	5
WB Walker at Murray	9037	0	8	5	0	18	0	0
WB Walker at Murray	9038	0	6	4	0	17	0	3
WB Walker at Murray	9039	0	8	3	0	13	0	-5
WB Walker at Murray	9040	1	12	7	0	28	0	5
WB Walker at Murray	9041	1	11	6	0	26	0	5
WB Walker at Murray	9042	0	5	2	0	15	0	6
WB Walker at Murray	9043	0	11	7	0	29	0	9
WB Walker at Murray	9044	1	12	7	0	27	0	5
WB Walker at Murray	9045	0	9	5	0	23	0	7
WB Walker at Murray	9046	1	8	4	0	16	0	0
WB Walker at Murray	9047	0	6	2	0	14	0	2
WB Walker at Murray	9048	1	8	5	0	26	0	11
WB Walker at Murray	9049	1	7	5	0	24	0	11
WB Walker at Murray	9050	0	5	5	0	20	0	11
WB Walker at Murray	9051	0	6	4	0	18	0	7
WB Walker at Murray	9052	0	6	5	0	28	0	19
WB Walker at Murray	9053	0	7	5	0	27	0	16
WB Walker at Murray	9054	0	8	5	0	25	0	12
WB Walker at Murray	9055	0	4	1	0	21	0	16
WB Walker at Murray	9056	0	17	12	0	25	0	-9
WB Walker at Murray	9057	0	10	6	0	19	0	-1
WB Walker at Murray	9058	0	10	5	0	14	0	-6
WB Walker at Murray	9059	1	6	3	0	9	0	-3
WB Walker at Murray	9060	0	0	0	-10	0	0	31
WB Walker at Murray	9061	0	1	0	-8	0	1	29

WB Walker at Murray	9062	0	2	0	6	0	2	27
WB Walker at Murray	9063	0	3	0	15	0	3	25
WB Walker at Murray	9064	0	4	0	27	0	4	23
WB Walker at Murray	9065	1	5	0	28	0	5	21
WB Walker at Murray	9066	0	5	1	30	0	4	21
WB Walker at Murray	9067	0	6	1	34	0	5	19
WB Walker at Murray	9068	0	7	1	36	0	6	17
WB Walker at Murray	9069	0	8	1	40	0	7	15
WB Walker at Murray	9070	0	9	1	42	0	8	13
WB Walker at Murray	9071	1	10	2	51	0	8	11
WB Walker at Murray	9072	1	10	3	55	0	7	11
WB Walker at Murray	9073	0	10	5	68	0	5	11
WB Walker at Murray	9074	0	11	5	70	0	6	9
WB Walker at Murray	9075	0	12	5	76	0	7	7
WB Walker at Murray	9076	0	0	0	-11	0	0	31
WB Walker at Murray	9077	1	1	0	-7	0	1	29
WB Walker at Murray	9078	0	1	1	2	0	0	29
WB Walker at Murray	9079	0	2	1	4	0	1	27
WB Walker at Murray	9080	0	3	1	19	0	2	25
WB Walker at Murray	9081	0	4	1	23	0	3	23
WB Walker at Murray	9082	1	5	2	30	0	3	21
WB Walker at Murray	9083	0	5	3	33	0	2	21
WB Walker at Murray	9084	0	6	3	35	0	3	19
WB Walker at Murray	9085	1	7	3	37	0	4	17
WB Walker at Murray	9086	1	7	4	40	0	3	17
WB Walker at Murray	9087	0	7	5	49	0	2	17
WB Walker at Murray	9088	0	8	6	60	0	2	15
WB Walker at Murray	9089	1	9	6	66	0	3	13

WB Walker at Murray	9090	0	9	7	70	0	2	13
WB Walker at Murray	9091	1	10	7	72	0	3	11
WB Walker at Murray	9092	0	10	8	74	0	2	11
WB Walker at Murray	9093	1	11	8	76	0	3	9
WB Walker at Murray	9094	0	11	9	78	0	2	9
WB Walker at Murray	9095	0	12	10	83	0	2	7
WB Walker at Murray	9096	0	13	10	88	0	3	5
WB Walker at Murray	9097	1	14	1	91	0	13	3
WB Walker at Murray	9098	0	1	0	-6	0	1	29
WB Walker at Murray	9099	0	2	1	5	0	1	27
WB Walker at Murray	9100	0	3	1	6	0	2	25
WB Walker at Murray	9101	0	4	3	16	0	1	23
WB Walker at Murray	9102	0	5	4	22	0	1	21
WB Walker at Murray	9103	0	6	4	27	0	2	19
WB Walker at Murray	9104	1	7	4	30	0	3	17
WB Walker at Murray	9105	1	7	5	42	0	2	17
WB Walker at Murray	9106	0	7	6	46	0	1	17
WB Walker at Murray	9107	1	8	7	57	0	1	15
WB Walker at Murray	9108	0	8	8	60	0	0	15
WB Walker at Murray	9109	0	9	8	61	0	1	13
WB Walker at Murray	9110	1	10	8	62	0	2	11
WB Walker at Murray	9111	0	10	9	66	0	1	11
WB Walker at Murray	9112	0	11	9	68	0	2	9
WB Walker at Murray	9113	0	12	9	70	0	3	7
WB Walker at Murray	9114	0	13	10	74	0	3	5
WB Walker at Murray	9115	1	14	10	77	0	4	3
WB Walker at Murray	9116	0	14	11	86	0	3	3
WB Walker at Murray	9117	0	0	0	-3	0	0	31

WB Walker at Murray	9118	1	1	0	3	0	1	29
WB Walker at Murray	9119	0	1	3	22	0	-2	29
WB Walker at Murray	9120	1	2	3	24	0	-1	27
WB Walker at Murray	9121	0	2	4	39	0	-2	27
WB Walker at Murray	9122	0	3	4	43	0	-1	25
WB Walker at Murray	9123	1	4	4	45	0	0	23
WB Walker at Murray	9124	0	4	5	47	0	-1	23
WB Walker at Murray	9125	0	5	6	51	0	-1	21
WB Walker at Murray	9126	0	0	0	-11	0	0	31
WB Walker at Murray	9127	0	1	1	-6	0	0	29
WB Walker at Murray	9128	1	2	2	-1	0	0	27
WB Walker at Murray	9129	0	3	2	1	0	1	25
WB Walker at Murray	9130	0	4	2	7	0	2	23
WB Walker at Murray	9131	1	4	2	11	0	2	23
WB Walker at Murray	9132	0	4	2	49	0	2	23
WB Walker at Murray	9133	1	5	2	57	0	3	21
WB Walker at Murray	9134	1	5	3	59	0	2	21
WB Walker at Murray	9135	0	5	4	61	0	1	21
WB Walker at Murray	9136	0	6	4	64	0	2	19
WB Walker at Murray	9137	0	7	5	72	0	2	17
WB Walker at Murray	9138	1	8	6	87	0	2	15
WB Walker at Murray	9139	0	0	0	-10	0	0	31
WB Walker at Murray	9140	0	1	1	-7	0	0	29
WB Walker at Murray	9141	0	2	0	9	0	2	27
WB Walker at Murray	9142	0	3	0	13	0	3	25
WB Walker at Murray	9143	0	4	0	17	0	4	23
WB Walker at Murray	9144	0	5	0	31	0	5	21
WB Walker at Murray	9145	0	6	0	32	0	6	19

WB Walker at Murray	9146	1	7	0	39	0	7	17
WB Walker at Murray	9147	0	7	1	42	0	6	17
WB Walker at Murray	9148	0	8	1	45	0	7	15
WB Walker at Murray	9149	0	9	1	46	0	8	13
WB Walker at Murray	9150	1	10	1	59	0	9	11
WB Walker at Murray	9151	0	10	2	63	0	8	11
WB Walker at Murray	9152	1	11	2	79	0	9	9
WB Walker at Murray	9153	1	11	3	88	0	8	9
WB Walker at Murray	9154	0	1	1	-1	0	0	29
WB Walker at Murray	9155	0	2	1	3	0	1	27
WB Walker at Murray	9156	0	3	1	5	0	2	25
WB Walker at Murray	9157	0	4	1	7	0	3	23
WB Walker at Murray	9158	0	5	0	18	0	5	21
WB Walker at Murray	9159	0	6	1	28	0	5	19
WB Walker at Murray	9160	0	7	2	88	0	5	17
WB Walker at Murray	9161	0	0	0	-11	0	0	31
WB Walker at Murray	9162	0	1	1	-6	0	0	29
WB Walker at Murray	9163	0	2	1	0	0	1	27
WB Walker at Murray	9164	0	3	1	2	0	2	25
WB Walker at Murray	9165	0	4	1	3	0	3	23
WB Walker at Murray	9166	0	5	1	5	0	4	21
WB Walker at Murray	9167	0	6	1	8	0	5	19
WB Walker at Murray	9168	0	7	1	10	0	6	17
WB Walker at Murray	9169	0	8	1	12	0	7	15
WB Walker at Murray	9170	0	9	1	14	0	8	13
WB Walker at Murray	9171	0	10	1	20	0	9	11
WB Walker at Murray	9172	1	11	1	23	0	10	9
WB Walker at Murray	9173	1	11	3	29	0	8	9

WB Walker at Murray	9174	0	11	4	31	0	7	9
WB Walker at Murray	9175	0	12	4	37	0	8	7
WB Walker at Murray	9176	0	13	4	42	0	9	5
WB Walker at Murray	9177	1	15	5	53	0	10	1
WB Walker at Murray	9178	0	15	7	64	0	8	1
WB Walker at Murray	9179	0	16	8	83	0	8	-1
WB Walker at Murray	9180	0	5	2	17	0	3	21
WB Walker at Murray	9181	0	6	3	27	0	3	19
WB Walker at Murray	9182	0	7	3	35	0	4	17
WB Walker at Murray	9183	0	8	3	41	0	5	15
WB Walker at Murray	9184	0	9	3	43	0	6	13
WB Walker at Murray	9185	1	10	3	45	0	7	11
WB Walker at Murray	9186	0	11	4	50	0	7	9
WB Walker at Murray	9187	0	12	4	52	0	8	7
WB Walker at Murray	9188	0	13	4	55	0	9	5
WB Walker at Murray	9189	1	14	5	60	0	9	3
WB Walker at Murray	9190	0	14	5	62	0	9	3
WB Walker at Murray	9191	0	15	5	67	0	10	1
WB Walker at Murray	9192	0	16	5	70	0	11	-1
WB Walker at Murray	9193	1	17	5	74	0	12	-3
WB Walker at Murray	9194	0	4	3	-17	0	1	23
WB Walker at Murray	9195	0	5	3	-12	0	2	21
WB Walker at Murray	9196	0	6	3	-9	0	3	19
WB Walker at Murray	9197	0	7	3	1	0	4	17
WB Walker at Murray	9198	0	8	3	3	0	5	15
WB Walker at Murray	9199	0	9	3	5	0	6	13
WB Walker at Murray	9200	0	10	3	7	0	7	11
WB Walker at Murray	9201	0	11	3	9	0	8	9

WB Walker at Murray	9202	1	12	4	24	0	8	7
WB Walker at Murray	9203	1	12	5	26	0	7	7
WB Walker at Murray	9204	0	12	6	29	0	6	7
WB Walker at Murray	9205	0	13	6	33	0	7	5
WB Walker at Murray	9206	0	14	6	35	0	8	3
WB Walker at Murray	9207	0	15	6	37	0	9	1
WB Walker at Murray	9208	0	16	6	39	0	10	-1
WB Walker at Murray	9209	1	17	6	42	0	11	-3
WB Walker at Murray	9210	0	17	7	52	0	10	-3
WB Walker at Murray	9211	0	18	7	57	0	11	-5
WB Walker at Murray	9212	0	19	7	66	0	12	-7
WB Walker at Murray	9213	1	20	7	70	0	13	-9
WB Walker at Murray	9214	0	21	7	75	0	14	-11
WB Walker at Murray	9215	1	22	7	84	0	15	-13
WB Walker at Murray	9216	0	23	8	90	0	15	-15
WB Walker at Murray	9217	0	7	3	-6	0	4	17
WB Walker at Murray	9218	1	8	3	-3	0	5	15
WB Walker at Murray	9219	1	8	4	-1	0	4	15
WB Walker at Murray	9220	0	8	5	13	0	3	15
WB Walker at Murray	9221	1	9	5	15	0	4	13
WB Walker at Murray	9222	0	9	6	18	0	3	13
WB Walker at Murray	9223	0	10	6	21	0	4	11
WB Walker at Murray	9224	0	11	6	23	0	5	9
WB Walker at Murray	9225	0	12	7	31	0	5	7
WB Walker at Murray	9226	0	13	7	34	0	6	5
WB Walker at Murray	9227	0	14	7	36	0	7	3
WB Walker at Murray	9228	1	15	7	38	0	8	1
WB Walker at Murray	9229	1	15	9	43	0	6	1

WB Walker at Murray	9230	0	15	10	47	0	5	1
WB Walker at Murray	9231	0	16	10	57	0	6	-1
WB Walker at Murray	9232	1	17	10	60	0	7	-3
WB Walker at Murray	9233	0	17	11	67	0	6	-3
WB Walker at Murray	9234	1	18	12	77	0	6	-5
WB Walker at Murray	9235	0	18	13	79	0	5	-5
WB Walker at Murray	9236	1	19	13	81	0	6	-7
WB Walker at Murray	9237	1	19	16	88	0	3	-7
WB Walker at Murray	9238	0	8	4	3	0	4	15
WB Walker at Murray	9239	0	9	4	8	0	5	13
WB Walker at Murray	9240	0	10	4	11	0	6	11
WB Walker at Murray	9241	1	11	4	16	0	7	9
WB Walker at Murray	9242	1	11	6	46	0	5	9
WB Walker at Murray	9243	0	11	7	51	0	4	9
WB Walker at Murray	9244	0	12	7	56	0	5	7
WB Walker at Murray	9245	0	13	8	60	0	5	5
WB Walker at Murray	9246	0	14	8	63	0	6	3
WB Walker at Murray	9247	0	15	10	76	0	5	1
WB Walker at Murray	9248	1	16	10	93	0	6	-1
WB Walker at Murray	9249	0	16	11	96	0	5	-1
WB Walker at Murray	9250	0	7	3	61	0	4	17
WB Walker at Murray	9251	0	8	3	63	0	5	15
WB Walker at Murray	9252	0	9	3	64	0	6	13
WB Walker at Murray	9253	1	10	3	66	0	7	11
WB Walker at Murray	9254	1	10	5	69	0	5	11
WB Walker at Murray	9255	1	11	4	73	0	7	9
WB Walker at Murray	9256	0	10	6	78	0	4	11
WB Walker at Murray	9257	0	11	6	81	0	5	9

WB Walker at Murray	9258	1	12	6	84	0	6	7
WB Walker at Murray	9259	1	12	7	88	0	5	7
WB Walker at Murray	9260	1	12	8	90	0	4	7
WB Walker at Murray	9261	0	12	10	95	0	2	7
WB Walker at Murray	9262	0	3	4	34	0	-1	25
WB Walker at Murray	9263	0	4	4	53	0	0	23
WB Walker at Murray	9264	1	5	4	57	0	1	21
WB Walker at Murray	9265	0	5	6	68	0	-1	21
WB Walker at Murray	9266	0	6	6	75	0	0	19
WB Walker at Murray	9267	0	7	7	84	0	0	17
WB Walker at Murray	9268	0	8	7	87	0	1	15
WB Walker at Murray	9269	0	9	7	89	0	2	13
WB Walker at Murray	9270	0	10	7	92	0	3	11
WB Walker at Murray	9271	0	11	7	95	0	4	9
WB Walker at Murray	9272	0	2	1	-4	0	1	27
WB Walker at Murray	9273	0	3	1	0	0	2	25
WB Walker at Murray	9274	1	4	0	5	0	4	23
WB Walker at Murray	9275	0	4	3	28	0	1	23
WB Walker at Murray	9276	0	5	4	51	0	1	21
WB Walker at Murray	9277	0	6	5	54	0	1	19
WB Walker at Murray	9278	1	7	5	56	0	2	17
WB Walker at Murray	9279	0	7	6	57	0	1	17
WB Walker at Murray	9280	1	8	6	60	0	2	15
WB Walker at Murray	9281	0	8	7	64	0	1	15
WB Walker at Murray	9282	0	9	7	66	0	2	13
WB Walker at Murray	9283	0	10	7	69	0	3	11
WB Walker at Murray	9284	0	11	7	72	0	4	9
WB Walker at Murray	9285	0	12	7	73	0	5	7

WB Walker at Murray	9286	0	13	7	82	0	6	5
WB Walker at Murray	9287	0	0	0	-7	0	0	31
WB Walker at Murray	9288	0	1	0	1	0	1	29
WB Walker at Murray	9289	0	2	0	18	0	2	27
WB Walker at Murray	9290	0	3	0	20	0	3	25
WB Walker at Murray	9291	0	4	0	23	0	4	23
WB Walker at Murray	9292	0	5	0	29	0	5	21
WB Walker at Murray	9293	0	6	1	49	0	5	19
WB Walker at Murray	9294	1	7	1	54	0	6	17
WB Walker at Murray	9295	1	7	2	56	0	5	17
WB Walker at Murray	9296	0	7	3	58	0	4	17
WB Walker at Murray	9297	0	8	4	62	0	4	15
WB Walker at Murray	9298	0	9	4	67	0	5	13
WB Walker at Murray	9299	0	10	5	74	0	5	11
WB Walker at Murray	9300	1	11	5	80	0	6	9
WB Walker at Murray	9301	0	1	2	-4	0	-1	29
WB Walker at Murray	9302	0	2	3	0	0	-1	27
WB Walker at Murray	9303	0	3	1	16	0	2	25
WB Walker at Murray	9304	1	4	1	23	0	3	23
WB Walker at Murray	9305	0	4	2	27	0	2	23
WB Walker at Murray	9306	1	5	2	32	0	3	21
WB Walker at Murray	9307	0	5	3	39	0	2	21
WB Walker at Murray	9308	0	6	4	50	0	2	19
WB Walker at Murray	9309	0	7	4	53	0	3	17
WB Walker at Murray	9310	1	8	4	55	0	4	15
WB Walker at Murray	9311	0	8	5	57	0	3	15
WB Walker at Murray	9312	0	9	5	60	0	4	13
WB Walker at Murray	9313	1	10	5	63	0	5	11

WB Walker at Murray	9314	1	10	6	65	0	4	11
WB Walker at Murray	9315	1	10	7	67	0	3	11
WB Walker at Murray	9316	0	10	8	80	0	2	11
WB Walker at Murray	9317	0	11	8	83	0	3	9
WB Walker at Murray	9318	0	12	8	93	0	4	7
WB Walker at Murray	9319	0	1	2	-5	0	-1	29
WB Walker at Murray	9320	0	2	2	1	0	0	27
WB Walker at Murray	9321	0	3	5	25	0	-2	25
WB Walker at Murray	9322	0	4	5	28	0	-1	23
WB Walker at Murray	9323	0	5	6	38	0	-1	21
WB Walker at Murray	9324	0	6	6	53	0	0	19
WB Walker at Murray	9325	0	7	6	67	0	1	17
WB Walker at Murray	9326	0	8	6	84	0	2	15
WB Walker at Murray	9327	0	9	6	88	0	3	13
WB Walker at Murray	9328	1	10	6	92	0	4	11
WB Walker at Murray	9329	0	10	7	94	0	3	11
WB Walker at Murray	9330	0	0	0	4	0	0	31
WB Walker at Murray	9331	0	1	0	21	0	1	29
WB Walker at Murray	9332	0	2	0	23	0	2	27
WB Walker at Murray	9333	1	3	0	25	0	3	25
WB Walker at Murray	9334	0	3	1	27	0	2	25
WB Walker at Murray	9335	0	4	2	67	0	2	23
WB Walker at Murray	9336	1	5	2	76	0	3	21
WB Walker at Murray	9337	1	5	3	80	0	2	21
WB Walker at Murray	9338	0	5	5	95	0	0	21
WB Walker at Murray	9339	0	0	0	-2	0	0	31
WB Walker at Murray	9340	1	1	0	2	0	1	29
WB Walker at Murray	9341	0	1	1	4	0	0	29

WB Walker at Murray	9342	0	2	1	7	0	1	27
WB Walker at Murray	9343	0	3	1	9	0	2	25
WB Walker at Murray	9344	0	4	1	13	0	3	23
WB Walker at Murray	9345	0	5	1	15	0	4	21
WB Walker at Murray	9346	1	6	1	17	0	5	19
WB Walker at Murray	9347	0	6	3	21	0	3	19
WB Walker at Murray	9348	0	7	3	23	0	4	17
WB Walker at Murray	9349	0	8	3	25	0	5	15
WB Walker at Murray	9350	1	9	3	26	0	6	13
WB Walker at Murray	9351	1	10	3	29	0	7	11
WB Walker at Murray	9352	0	10	4	31	0	6	11
WB Walker at Murray	9353	0	11	4	33	0	7	9
WB Walker at Murray	9354	0	12	4	40	0	8	7
WB Walker at Murray	9355	0	13	7	47	0	6	5
WB Walker at Murray	9356	1	15	8	66	0	7	1
WB Walker at Murray	9357	1	16	9	87	0	7	-1
WB Walker at Murray	9358	0	16	10	89	0	6	-1
WB Walker at Murray	9359	1	17	10	93	0	7	-3

TABLE B-3. Simulated Disaggregate Model ATL Flows for Model Comparison

Approach	Field Observed Flow	Aggregate Model Flow	Simulated Disaggregate Model Flows (Runs 1-15)														
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
NB Garrett	42	38	20	48	44	32	24	44	20	32	16	48	32	32	32	44	8
NB Garrett	47	57	68	80	52	48	44	64	56	52	52	80	56	44	40	72	64
NB Garrett	49	75	92	76	72	92	68	72	76	92	48	84	88	48	80	96	88
NB Garrett	44	50	48	32	56	40	40	56	64	52	64	72	72	60	48	60	64
NB Garrett	86	68	64	76	60	52	84	72	92	56	76	32	84	84	64	76	72
NB Garrett	51	44	36	32	36	40	60	72	48	48	60	36	44	40	40	48	36
NB Garrett	50	44	44	52	44	40	48	44	24	36	64	52	40	56	48	60	40
NB Garrett	25	35	40	44	8	44	24	16	24	28	20	20	24	28	32	36	32
NB Garrett	34	45	64	40	64	44	48	52	52	56	32	44	32	36	44	44	40
SB Garrett	49	42	44	28	32	52	20	52	40	28	40	48	16	60	24	40	24
SB Garrett	74	56	56	56	68	56	64	68	44	52	44	52	68	80	56	48	36
SB Garrett	71	49	68	52	48	40	56	52	52	24	80	52	60	48	52	56	40
SB Garrett	41	52	64	52	64	76	68	56	68	56	32	48	76	48	68	56	40
SB Garrett	60	46	52	32	52	60	76	48	44	44	60	40	52	40	32	40	32
NB La Canada	80	88	92	88	56	128	84	76	80	136	72	96	116	92	96	84	96
NB La Canada	84	117	140	124	160	144	148	128	108	120	188	148	116	108	156	144	80
NB La Canada	112	103	88	148	72	104	128	116	132	136	104	108	100	140	128	100	128
NB La Canada	124	134	156	172	168	104	136	124	136	164	124	96	128	148	124	112	144
NB La Canada	204	195	164	160	236	164	168	204	232	168	232	204	240	176	168	176	172
NB La Canada	132	138	140	140	148	168	196	172	152	152	168	152	140	160	108	164	164
NB La Canada	116	152	184	160	132	196	156	228	116	156	180	116	140	184	112	128	156
NB La Canada	168	174	200	156	196	180	188	164	168	168	160	208	176	156	192	232	160
NB La Canada	156	148	128	116	148	128	176	136	152	136	132	184	184	116	132	156	152

Approach	Field Observed Flow	Aggregate Model Flow	Simulated Disaggregate Model Flows (Runs 16-35)																			
			16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
NB Garrett	42	38	32	48	20	44	60	8	32	32	32	24	28	52	40	20	44	32	40	40	52	20
NB Garrett	47	57	64	52	76	72	84	52	60	64	44	64	60	72	36	108	44	52	56	36	52	40
NB Garrett	49	75	108	68	64	68	56	88	64	88	84	68	68	108	60	68	80	92	108	76	52	72
NB Garrett	44	50	44	32	64	36	32	44	48	36	56	24	36	84	24	52	56	72	60	64	44	64
NB Garrett	86	68	80	48	44	72	44	48	76	72	80	68	84	84	48	48	72	64	72	52	52	48
NB Garrett	51	44	40	32	52	48	48	48	36	28	60	40	64	36	56	68	32	44	48	60	36	32
NB Garrett	50	44	68	44	12	36	44	52	48	40	24	44	44	32	24	48	60	44	32	28	40	36
NB Garrett	25	35	24	24	32	16	32	40	24	28	36	40	32	24	56	28	28	24	52	36	20	36
NB Garrett	34	45	56	40	44	52	52	20	64	56	72	56	40	36	44	48	36	36	48	80	52	44
SB Garrett	49	42	44	28	68	32	60	20	28	48	60	40	36	24	28	48	24	24	20	36	28	36
SB Garrett	74	56	68	72	56	60	100	60	72	48	56	48	92	44	76	52	60	88	92	40	44	52
SB Garrett	71	49	36	60	44	44	52	36	32	60	40	60	48	56	60	52	28	56	44	44	64	40
SB Garrett	41	52	40	48	56	32	52	40	60	64	52	56	72	40	60	36	40	44	32	40	36	52
SB Garrett	60	46	28	32	40	36	56	44	72	16	28	52	36	60	60	36	32	52	56	48	48	72
NB La Canada	80	88	112	92	112	124	72	64	92	112	68	108	96	124	76	112	124	112	124	76	116	112
NB La Canada	84	117	152	120	172	88	116	100	108	116	160	108	132	132	88	120	124	140	152	120	160	140
NB La Canada	112	103	116	128	76	148	88	140	128	96	104	148	124	76	112	136	128	120	100	136	140	136
NB La Canada	124	134	136	140	168	144	108	136	128	164	176	156	120	176	156	132	140	140	132	136	132	112
NB La Canada	204	195	140	212	192	176	240	180	144	140	204	172	140	176	220	180	212	192	188	180	180	168
NB La Canada	132	138	104	136	132	116	128	136	136	136	176	160	160	188	148	156	104	132	116	172	152	124
NB La Canada	116	152	122	136	112	136	140	196	156	188	140	124	148	124	160	148	152	184	132	124	152	156
NB La Canada	168	174	156	176	184	174	196	176	188	196	176	200	200	168	172	184	172	148	140	188	156	188
NB La Canada	156	148	156	152	164	164	172	160	172	156	180	140	148	156	152	176	140	140	164	140	124	164

Approach	Field Observed Flow	Aggregate Model Flow	Simulated Disaggregate Model Flows (Runs 36-50)															Disaggregate Model Flow (Average of Runs 1-50)
			36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	
NB Garrett	42	38	36	40	52	28	20	28	48	48	32	16	20	44	44	40	52	34
NB Garrett	47	57	56	40	28	56	84	52	32	72	72	44	68	52	64	48	72	58
NB Garrett	49	75	72	76	80	52	88	80	56	68	64	60	84	88	72	80	72	76
NB Garrett	44	50	40	40	68	76	44	44	40	56	44	64	44	40	56	64	56	60
NB Garrett	86	68	80	72	88	72	100	92	84	48	64	64	64	88	72	60	80	69
NB Garrett	51	44	28	44	40	52	40	16	40	56	28	36	52	36	44	36	40	43
NB Garrett	50	44	40	48	40	48	40	36	48	44	48	48	44	44	52	44	76	44
NB Garrett	25	35	8	40	36	36	40	48	56	40	16	48	0	16	36	20	12	30
NB Garrett	34	45	60	36	32	32	76	60	48	56	20	36	64	52	24	44	40	47
SB Garrett	49	42	56	32	48	44	20	56	52	56	52	44	48	52	32	64	48	40
SB Garrett	74	56	56	44	40	60	72	72	84	80	60	84	40	72	52	60	84	62
SB Garrett	71	49	56	44	48	48	68	36	44	44	48	60	36	52	48	48	44	49
SB Garrett	41	52	84	56	60	48	80	52	36	40	80	60	68	56	36	60	48	54
SB Garrett	60	46	40	52	28	24	60	44	36	44	36	40	60	64	40	56	36	45
NB La Canada	80	88	88	64	120	120	104	108	116	124	92	108	104	52	112	84	92	98
NB La Canada	84	117	128	124	108	100	96	152	104	116	140	136	128	100	108	160	112	127
NB La Canada	112	103	100	104	116	104	120	128	132	156	108	112	88	132	128	116	120	118
NB La Canada	124	134	124	136	140	152	132	132	148	88	148	108	108	120	108	116	128	135
NB La Canada	204	195	192	204	200	192	192	168	212	172	216	148	184	212	184	236	168	188
NB La Canada	132	138	132	172	124	100	140	104	164	160	156	148	180	132	164	172	128	146
NB La Canada	116	152	176	116	140	112	136	152	152	168	168	164	140	140	160	144	156	150
NB La Canada	168	174	140	136	148	136	180	212	164	164	216	164	148	204	196	160	144	175
NB La Canada	156	148	164	164	188	124	108	140	116	200	116	168	148	112	132	164	156	150

Approach	Field Observed Flow	Aggregate Model Flow	Simulated Disaggregate Model Flows (Runs 1-15)														
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SB La Canada	88	95	120	68	108	132	80	112	88	100	136	140	92	104	112	120	104
SB La Canada	100	75	96	100	128	48	76	80	104	80	104	72	80	84	136	116	80
SB La Canada	124	104	76	184	100	92	116	124	124	88	80	100	120	124	152	140	112
SB La Canada	128	107	116	148	108	112	96	104	104	144	88	128	116	140	136	168	144
SB La Canada	56	71	100	68	80	108	80	92	60	96	84	104	96	64	88	108	60
SB La Canada	84	86	112	112	96	100	116	140	92	72	92	80	80	120	108	108	104
SB La Canada	80	73	100	132	92	100	68	68	96	84	100	108	72	68	76	52	64
SB La Canada	152	87	96	104	128	96	88	88	124	120	100	136	96	108	104	76	84
EB Magee	64	57	48	64	48	68	52	72	48	48	60	68	84	76	60	60	48
EB Magee	53	57	52	48	40	64	60	60	40	48	44	72	88	52	64	48	60
EB Magee	80	83	80	80	60	72	60	64	52	76	92	92	140	80	80	112	88
EB Magee	107	120	128	116	128	84	88	92	112	128	108	132	92	132	96	120	108
EB Magee	61	54	80	56	80	60	48	44	60	84	56	84	60	60	48	56	52
EB Magee	79	87	100	84	80	84	40	88	100	80	84	68	88	92	96	60	68
EB Magee	76	96	104	92	68	72	44	100	64	80	96	112	88	108	124	136	104
EB Magee	88	78	76	60	84	104	68	80	88	60	88	68	88	84	84	108	72
EB Magee	68	85	92	84	88	76	80	76	88	80	88	88	96	80	100	68	60
EB Magee	72	118	116	140	84	128	124	96	124	118	148	84	88	128	88	132	76
EB Magee	99	85	88	68	88	80	68	84	68	60	88	88	64	44	120	88	72
EB Magee	68	87	108	64	76	80	60	104	104	64	92	60	84	104	76	52	104
EB Magee	72	92	104	64	84	108	108	76	112	80	56	92	72	156	100	92	68
WB Magee	56	59	56	76	84	116	72	112	80	72	84	96	68	84	76	128	44
WB Magee	60	87	92	56	124	140	88	88	72	84	96	88	100	84	92	108	84
WB Magee	64	51	72	56	68	96	40	68	60	56	28	64	64	64	64	72	60
WB Magee	56	54	24	64	76	72	28	68	64	64	84	56	52	40	44	84	52
WB Magee	63	53	68	72	44	68	60	64	64	84	44	68	72	80	52	80	128
WB Magee	36	38	68	56	68	48	72	60	68	60	68	64	80	48	56	48	60
WB Magee	28	36	76	32	56	80	36	72	60	52	56	76	60	52	60	36	56

Approach	Field Observed Flow	Aggregate Model Flow	Simulated Disaggregate Model Flows (Runs 16-35)																			
			16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
SB La Canada	88	95	104	112	108	124	132	116	100	104	104	104	108	76	140	100	76	120	132	116	128	120
SB La Canada	100	75	100	100	108	116	76	72	108	96	80	124	100	104	80	60	92	104	112	80	84	92
SB La Canada	124	104	116	164	120	132	112	92	152	132	108	144	108	112	116	124	104	132	128	140	152	200
SB La Canada	128	107	136	144	152	140	120	160	156	92	164	120	160	112	112	164	116	120	108	132	112	108
SB La Canada	56	71	108	112	96	112	108	80	72	112	72	104	120	128	108	84	112	112	88	88	80	96
SB La Canada	84	86	132	112	96	112	96	92	132	132	152	80	108	108	76	88	132	84	104	76	128	108
SB La Canada	80	73	112	120	64	72	108	104	88	88	80	88	96	112	92	140	72	112	84	84	112	84
SB La Canada	152	87	108	112	120	116	96	120	112	116	104	88	40	92	72	116	156	112	104	104	120	104
EB Magee	64	57	64	52	60	64	48	76	52	56	84	60	52	56	64	60	44	48	56	68	48	76
EB Magee	53	57	48	36	60	40	64	52	60	88	80	72	48	48	56	56	56	32	80	84	68	64
EB Magee	80	83	48	56	80	108	92	80	108	68	132	80	60	92	60	72	68	76	76	100	76	100
EB Magee	107	120	76	140	132	116	124	140	88	120	124	152	104	88	104	104	116	112	120	80	108	116
EB Magee	61	54	48	44	64	40	60	32	60	72	48	44	52	76	76	36	56	60	48	64	68	76
EB Magee	79	87	64	72	72	100	84	88	96	108	68	80	92	72	64	80	76	64	96	128	124	100
EB Magee	76	96	112	100	84	76	64	64	104	96	60	60	132	104	144	128	76	76	88	124	92	84
EB Magee	88	78	64	64	72	64	52	68	40	84	84	56	80	96	76	72	96	56	88	100	56	96
EB Magee	68	85	92	96	80	76	92	88	76	64	92	96	64	104	72	80	116	76	100	100	56	132
EB Magee	72	118	124	88	76	96	116	120	92	88	104	112	108	116	128	120	116	108	96	88	132	124
EB Magee	99	85	88	80	76	72	68	80	60	52	104	60	108	68	104	80	56	92	96	44	72	76
EB Magee	68	87	100	56	84	68	76	60	60	72	64	108	76	72	104	104	68	80	96	96	88	72
EB Magee	72	92	84	80	52	100	128	96	64	92	92	60	88	76	104	88	88	112	64	84	80	104
WB Magee	56	59	72	72	92	60	108	64	100	88	88	64	104	92	76	84	116	100	64	56	76	44
WB Magee	60	87	140	100	100	88	92	96	104	92	108	104	88	120	92	100	80	84	68	112	72	92
WB Magee	64	51	60	104	60	52	68	72	100	56	88	52	48	76	72	60	76	68	40	44	52	72
WB Magee	56	54	72	80	68	68	68	68	76	56	76	48	32	56	48	76	48	92	64	44	72	88
WB Magee	63	53	84	80	76	56	64	72	80	76	88	84	88	64	56	88	84	108	84	76	88	92
WB Magee	36	38	76	52	64	80	68	32	68	44	48	56	32	44	64	52	56	40	72	72	48	60
WB Magee	28	36	48	40	64	56	48	40	32	88	60	76	68	84	52	56	40	60	56	72	40	64

Approach	Field Observed Flow	Aggregate Model Flow	Simulated Disaggregate Model Flows (Runs 36-50)															Disaggregate Model Flow (Average of Runs 1-50)
			36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	
SB La Canada	88	95	108	116	152	128	160	120	108	112	128	72	120	112	132	124	80	112
SB La Canada	100	75	108	108	96	120	88	144	92	136	100	92	120	84	84	104	88	97
SB La Canada	124	104	128	112	132	128	128	152	148	148	128	124	104	148	96	92	156	125
SB La Canada	128	107	128	84	108	148	108	88	140	104	148	104	140	110	148	108	172	126
SB La Canada	56	71	96	88	112	104	124	96	104	80	80	100	72	52	88	56	72	92
SB La Canada	84	86	116	108	88	120	60	84	120	116	96	100	112	76	108	68	112	103
SB La Canada	80	73	76	80	88	120	104	84	76	116	100	128	72	108	64	116	104	93
SB La Canada	152	87	112	104	128	84	144	92	140	112	104	132	88	84	100	92	88	105
EB Magee	64	57	76	52	64	88	60	72	52	48	76	56	88	60	52	32	60	61
EB Magee	53	57	56	60	48	84	76	64	56	72	48	48	72	52	60	64	52	59
EB Magee	80	83	60	124	76	96	92	104	120	56	112	76	68	80	120	40	112	84
EB Magee	107	120	100	104	156	108	88	116	80	96	160	112	104	164	112	128	148	114
EB Magee	61	54	72	60	56	76	68	44	64	48	68	44	60	52	36	48	64	58
EB Magee	79	87	88	104	80	128	100	108	68	76	72	92	80	120	60	80	64	85
EB Magee	76	96	124	88	76	64	76	84	112	44	104	112	80	104	72	132	84	92
EB Magee	88	78	68	80	92	64	60	92	104	68	52	88	76	68	108	56	96	77
EB Magee	68	85	104	80	64	80	68	80	112	112	88	60	108	68	60	60	64	84
EB Magee	72	118	112	96	80	124	128	100	128	120	108	140	100	92	112	60	120	109
EB Magee	99	85	92	92	80	80	76	76	96	68	68	44	68	56	88	104	76	77
EB Magee	68	87	92	108	68	88	112	124	88	56	76	76	84	100	64	72	84	83
EB Magee	72	92	104	92	92	128	76	84	60	116	96	116	84	72	100	80	84	90
WB Magee	56	59	84	48	92	108	64	92	80	84	80	60	100	72	56	56	72	80
WB Magee	60	87	64	60	76	88	72	104	80	116	68	80	124	108	88	88	128	93
WB Magee	64	51	88	44	64	100	44	76	80	60	76	60	64	104	60	60	96	67
WB Magee	56	54	64	60	72	68	52	76	96	26	56	48	68	96	64	52	76	63
WB Magee	63	53	68	56	108	44	32	64	84	80	92	68	84	68	72	92	52	74
WB Magee	36	38	72	92	80	40	56	80	64	52	60	56	60	40	68	56	64	60
WB Magee	28	36	68	56	36	60	60	52	40	60	40	52	72	60	72	60	64	57

Approach	Field Observed Flow	Aggregate Model Flow	Simulated Disaggregate Model Flows (Runs 1-15)														
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
EB Walker at 185	122	104	104	108	112	92	84	64	88	112	76	88	84	132	92	60	68
EB Walker at 185	121	91	52	52	60	36	68	120	72	60	108	84	124	68	60	76	96
EB Walker at 185	144	120	80	68	124	116	108	120	108	112	96	92	64	84	52	72	64
EB Walker at 185	167	130	60	144	100	124	132	96	112	84	84	84	92	92	116	80	128
EB Walker at 185	237	221	112	232	200	144	188	178	196	152	224	136	136	156	156	168	136
EB Walker at 185	185	147	88	112	112	96	128	128	124	140	140	96	116	100	92	124	140
EB Walker at 185	224	186	108	112	160	132	152	124	140	128	124	132	108	120	120	152	116
EB Walker at 185	161	128	120	80	116	84	88	108	112	168	64	112	108	48	108	116	88
WB Walker at Murray	150	119	132	96	120	128	108	112	96	96	124	72	128	132	112	64	112
WB Walker at Murray	179	184	168	124	180	204	156	140	176	136	152	156	192	160	128	172	156
WB Walker at Murray	114	119	120	136	96	88	164	128	104	128	124	96	120	112	76	160	104
WB Walker at Murray	156	152	168	132	136	104	120	128	116	96	164	128	128	144	128	184	180
WB Walker at Murray	171	157	196	92	168	180	124	156	108	144	212	100	152	116	172	136	112
WB Walker at Murray	183	222	164	224	260	180	224	192	128	164	152	144	228	188	236	212	216

Approach	Field Observed Flow	Aggregate Model Flow	Simulated Disaggregate Model Flows (Runs 16-35)																			
			16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
EB Walker at 185	122	104	88	104	68	92	88	96	64	88	80	60	68	40	76	76	80	56	96	96	68	80
EB Walker at 185	121	91	96	76	88	80	64	60	68	88	124	80	76	72	88	88	84	60	64	56	116	88
EB Walker at 185	144	120	136	124	108	76	64	72	100	104	96	96	96	108	128	84	84	64	96	96	88	80
EB Walker at 185	167	130	104	60	132	64	116	112	124	128	88	84	112	108	124	104	104	84	116	88	104	80
EB Walker at 185	237	221	156	148	184	120	140	172	164	196	148	168	176	164	140	176	180	132	264	96	136	116
EB Walker at 185	185	147	112	88	120	112	140	136	88	152	132	116	124	92	88	132	88	132	96	120	120	116
EB Walker at 185	224	186	148	108	148	136	96	160	176	144	136	168	148	176	100	176	132	112	152	128	116	148
EB Walker at 185	161	128	84	120	108	96	80	108	144	92	120	80	120	92	72	56	80	96	92	92	108	116
WB Walker at Murray	150	119	132	108	52	120	128	140	132	108	96	84	128	132	144	128	140	124	108	76	92	116
WB Walker at Murray	179	184	100	212	148	156	196	156	180	176	160	180	128	176	184	156	124	152	128	124	136	144
WB Walker at Murray	114	119	116	88	100	168	120	116	116	104	96	140	120	104	120	108	136	104	88	96	104	128
WB Walker at Murray	156	152	124	92	120	144	172	148	116	184	152	174	172	96	128	124	180	108	112	160	108	148
WB Walker at Murray	171	157	124	152	128	156	128	112	132	88	132	128	160	200	128	124	156	96	124	108	132	132
WB Walker at Murray	183	222	204	264	144	172	204	136	172	148	216	168	204	276	176	184	172	148	168	168	188	164

Approach	Field Observed Flow	Aggregate Model Flow	Simulated Disaggregate Model Flows (Runs 36-50)															Disaggregate Model Flow (Average of Runs 1-50)
			36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	
EB Walker at 185	122	104	40	104	68	84	96	68	76	84	48	84	96	84	108	112	108	84
EB Walker at 185	121	91	64	60	60	68	84	96	104	96	40	52	56	60	52	88	48	76
EB Walker at 185	144	120	88	68	60	100	96	80	96	76	64	104	96	72	72	80	84	90
EB Walker at 185	167	130	152	112	132	96	76	96	68	88	80	100	100	136	100	88	96	102
EB Walker at 185	237	221	264	200	180	172	172	164	124	160	164	200	140	176	204	156	204	167
EB Walker at 185	185	147	164	116	108	156	96	128	116	104	96	112	116	88	112	104	120	116
EB Walker at 185	224	186	140	152	144	108	156	140	248	120	164	116	108	136	84	120	148	136
EB Walker at 185	161	128	72	108	88	76	76	104	76	120	56	92	84	84	124	104	112	97
WB Walker at Murray	150	119	120	112	96	80	96	88	120	64	96	112	64	72	104	152	88	108
WB Walker at Murray	179	184	188	168	140	120	164	172	184	124	116	132	136	168	168	164	204	157
WB Walker at Murray	114	119	124	92	100	148	136	112	112	112	84	140	96	104	152	96	140	116
WB Walker at Murray	156	152	112	116	132	116	88	140	136	104	96	108	152	156	156	112	112	133
WB Walker at Murray	171	157	180	156	136	112	136	156	132	160	152	160	160	136	112	160	88	139
WB Walker at Murray	183	222	176	196	144	172	200	212	204	200	188	208	248	252	188	240	204	192

C AGGREGATE MODEL DETAILS

This appendix contains a description of all aggregate models and data relationships not contained within the body of Chapter 3. The author's intent is to provide the critical information relating to the contributions of Chapters 3 within the text of that chapter. However, in order for this research to be reproducible, this appendix provides all models and figures not contained within the results or discussion of Chapter 3.

Aggregate Model Visualization

One of the most surprising findings of this research is that ATL use does not appear to be related to downstream ATL length, which is contrary to many of the hypotheses in the literature (Section 2.1.3). Although the operation of the ATL is closely tied to the upstream length (in order to prevent blockage of the ATL by the CTL queue), it does not appear that more drivers will use the ATL if a longer downstream length is provided. Figure C-1 displays a plot of ATL flow against ATL downstream length.

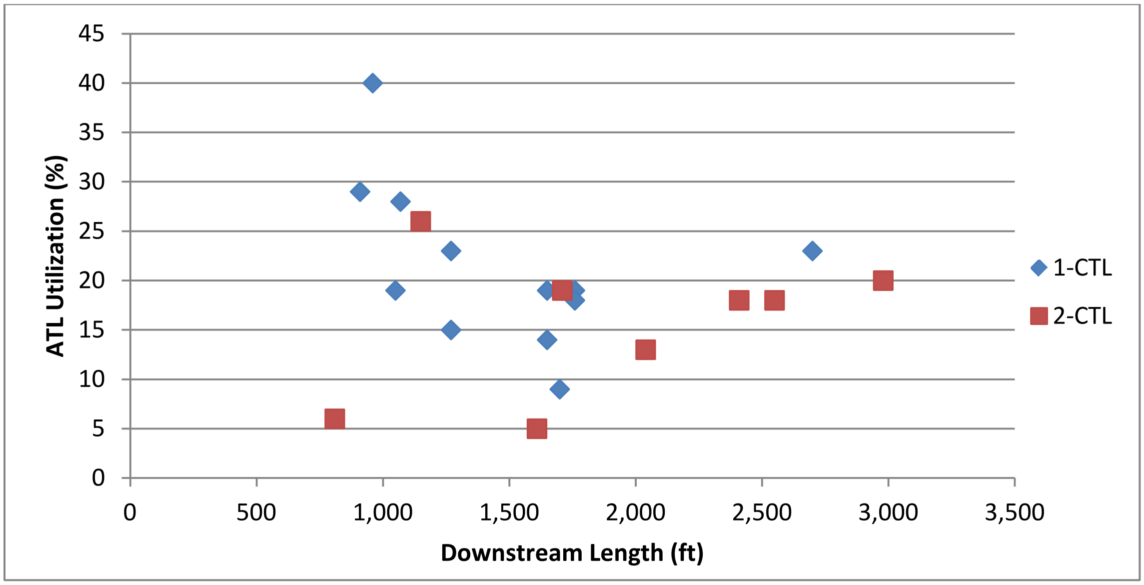

FIGURE C-1. ATL Utilization versus Downstream Length

The figure indicates that there is relatively no relationship between ATL utilization and downstream length for either the 1-CTL or 2-CTL sites, as well as for all sites combined. In fact, the 1-CTL sites with the shortest downstream length appear to have the highest ATL utilization, which may be related to the tendency of these sites to be located in urban or suburban areas where dense development (which may have caused higher demand and, consequently, more ATL use) has constrained the downstream ATL length to a shorter distance.

The author also hypothesized that heavy vehicles might influence ATL use, as drivers may be less inclined to choose a lane with a heavy vehicle in queue. However, this relationship was difficult to quantify in terms of an aggregate model, as displayed in Figure C-2. The same difficulty arises when examining the relationship between ATL flow and delay saving, which is displayed in Figure C-3.

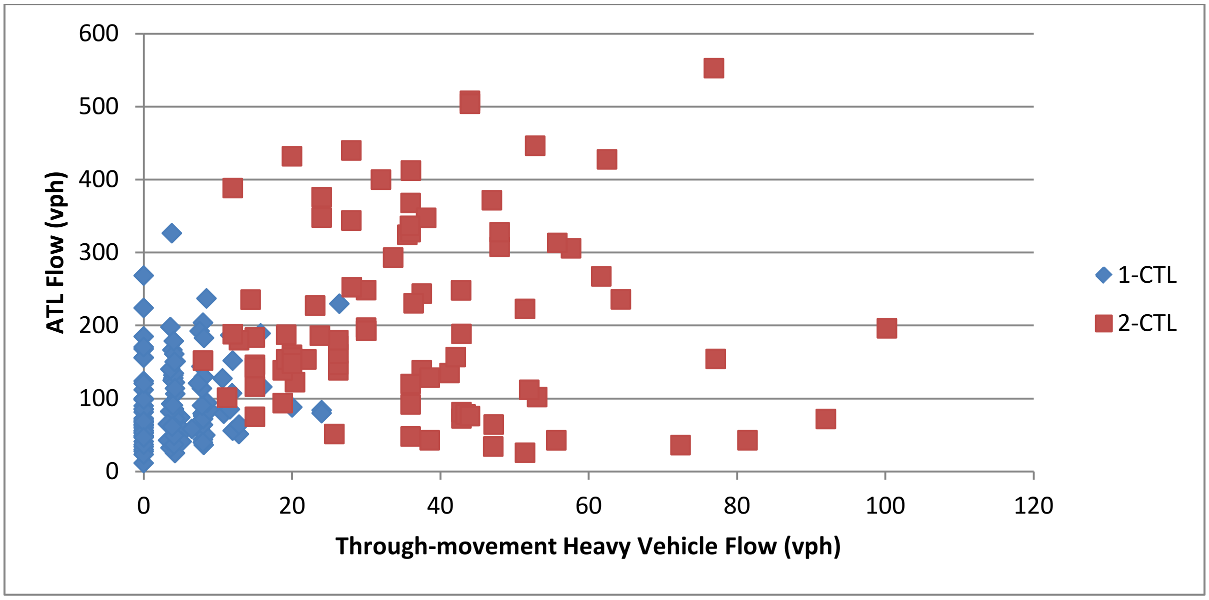

FIGURE C-2. ATL Flow versus Total Through-movement Heavy Vehicle Flow

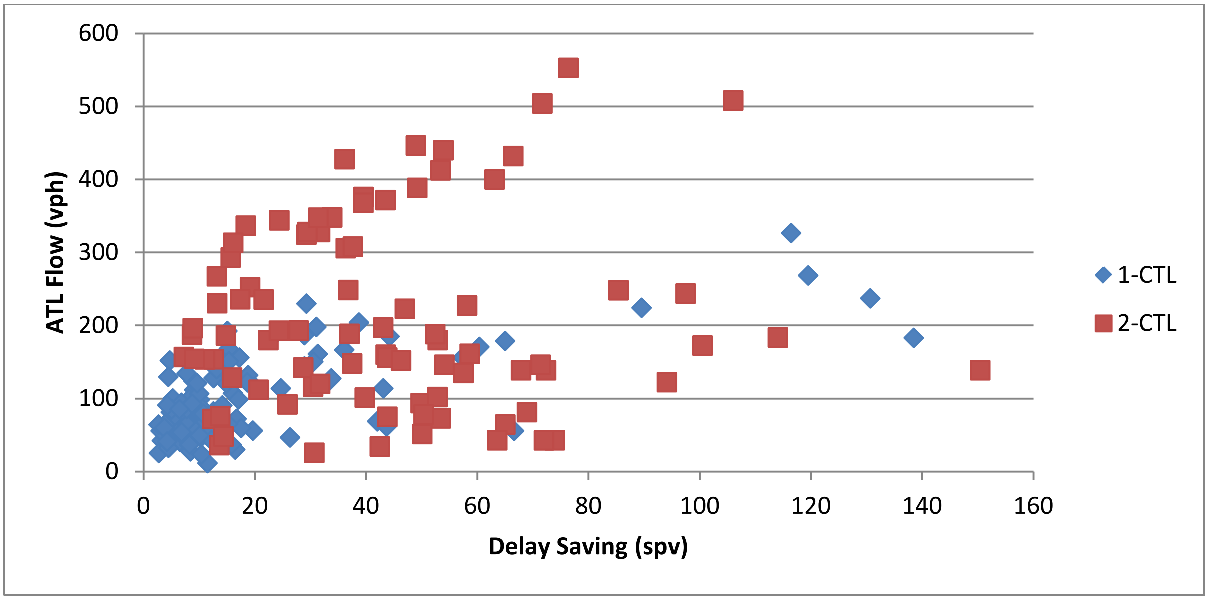

FIGURE C-3. ATL Flow versus Delay Saving

Figure C-3 indicates that ATL flow increases as the delay saving (i.e. the difference in hypothetical travel time between the CTL and ATL based upon the HCM delay equations) increases, but this relationship may be clouded due to correlation between delay saving and congestion, which the author has already surmised to strongly affect ATL use. The 1-CTL data even has a weakly positive ($R^2 = 0.48$) relationship, but such trends may be better accounted for within a microsimluation environment (Chapters 4 and 6).

For purposes of completeness, the author has also included an ANCOVA analysis for some of the trends shown in Section 3.3.1. This analysis is important in that it tests for site-to-site differences in slope (where each line represents the relationship between ATL flow and the explanatory variable for a different site). The author repeated this procedure for ATL flow versus total through-movement flow and for ATL flow versus X_T, two of the strongest relationships evident in the data. Tables C-1 through C-4 display the SAS output for the ANCOVA procedure for the relationships displayed in Figures 3-1 (Tables C-1 and C-2) and 3-2 (Tables C-3 and C-4).

.TABLE C-1. ANCOVA Output for 1-CTL Data (ATL Flow versus Through Flow)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	27	351294.8389	13010.9200	48.84	<.0001
Error	94	25042.2416	266.4068		
Corrected Total	121	376337.0805			

R-Square	Coeff Var	Root MSE	ATL_Vol Mean
0.933458	16.99509	16.32197	96.03932

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Site	13	250549.7555	19273.0581	72.34	<.0001
Thru_Vol	1	91447.3524	91447.3524	343.26	<.0001
Thru_Vol*Site	13	9297.7310	715.2101	2.68	0.0030

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Site	13	4944.157731	380.319825	1.43	0.1613
Thru_Vol	1	7495.976741	7495.976741	28.14	<.0001
Thru_Vol*Site	13	9297.730977	715.210075	2.68	0.0030

TABLE C-2. ANCOVA Output for 2-CTL Data (ATL Flow versus Through Flow)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	13	1141970.540	87843.888	79.31	<.0001
Error	60	66453.842	1107.564		
Corrected Total	73	1208424.382			

R-Square	Coeff Var	Root MSE	ATL_Vol Mean
0.945008	14.73179	33.28008	225.9066

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Site	6	899925.7937	149987.6323	135.42	<.0001
Thru_Vol	1	226908.2167	226908.2167	204.87	<.0001
Thru_Vol*Site	6	15136.5298	2522.7550	2.28	0.0479

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Site	6	11799.42301	1966.57050	1.78	0.1195
Thru_Vol	1	72588.71170	72588.71170	65.54	<.0001
Thru_Vol*Site	6	15136.52983	2522.75497	2.28	0.0479

TABLE C-3. ANCOVA Output for 1-CTL Data (ATL Flow versus X_T)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	27	349431.2093	12941.8966	45.21	<.0001
Error	94	26905.8712	286.2327		
Corrected Total	121	376337.0805			

R-Square	Coeff Var	Root MSE	ATL_Vol Mean
0.928506	17.61613	16.91841	96.03932

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Site	13	250549.7555	19273.0581	67.33	<.0001
X_T	1	81507.9296	81507.9296	284.76	<.0001
X_T*Site	13	17373.5242	1336.4249	4.67	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Site	13	5375.90462	413.53112	1.44	0.1539
X_T	1	12017.68209	12017.68209	41.99	<.0001
X_T*Site	13	17373.52418	1336.42494	4.67	<.0001

TABLE C-4. ANCOVA Output for 2-CTL Data (ATL Flow versus X_T)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	13	1143214.585	87939.583	80.91	<.0001
Error	60	65209.798	1086.830		
Corrected Total	73	1208424.382			

R-Square	Coeff Var	Root MSE	ATL_Vol Mean
0.946037	14.59324	32.96710	225.9066

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Site	6	899925.7937	149987.6323	138.00	<.0001
X_T	1	179395.6402	179395.6402	165.06	<.0001
X_T*Site	6	63893.1509	10648.8585	9.80	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Site	6	19316.9648	3219.4941	2.96	0.0134
X_T	1	112572.5461	112572.5461	103.58	<.0001
X_T*Site	6	63893.1509	10648.8585	9.80	<.0001

Each of the analyses indicates that the interaction term between the independent variable and a categorical variable for each site is significant, which means that different sites may have different slopes.

Site-to-Site Variability versus Variability Within Sites

This section contains a discussion of the variability in the aggregate data and how much of the variability can be attributed to site-to-site differences in the data (as opposed to variability within each site). The author explored this variability by comparing the mean squared error of the models (shown in Tables 3-5 and 3-6) with the following ratio:

$$\frac{Site\ MSE - ModelMSE}{Site\ Type\ III\ Expected\ MS}$$

In this case, the site effect was modeled as a random effect because each site is essentially sampled from a population of sites. In this comparison, the author found that the ratio listed above and the model MSE were not practically different (i.e. within the same magnitude), indicating that the variability due to site effects was not much greater than the variability within each site.

D DISAGGREGATE MODEL DETAILS

This appendix contains a description of all disaggregate models and data relationships not contained within the body of Chapter 4. The author’s intent is to provide the critical information relating to the contributions of Chapters 4 within the text of that chapter. However, in order for this research to be reproducible, this appendix provides all models and figures not contained within the results or discussion of Chapter 4. Figures D-1 through D-4 display the probability of ATL use as a function of the CTL queue, queue difference, and arrival phase for each of the site models. Figures D-1 and D-2 contain two of the arrivals in red model types, Figure D-3 contains the first model type for the arrivals in green models, and Figure D-4 contains the first model type for the combined arrivals models. Only the selected models are presented—models which contained more than one explanatory variable are not displayed because the figures would be very complex, and the author feels that the reader can achieve a reasonable understanding of the model sensitivity from the plots shown. Furthermore, the models which contained the terms for green time remaining and time to clear intersection are not displayed because these relationships were not consistent with trends observed in the field (see discussion in Section 4.3).

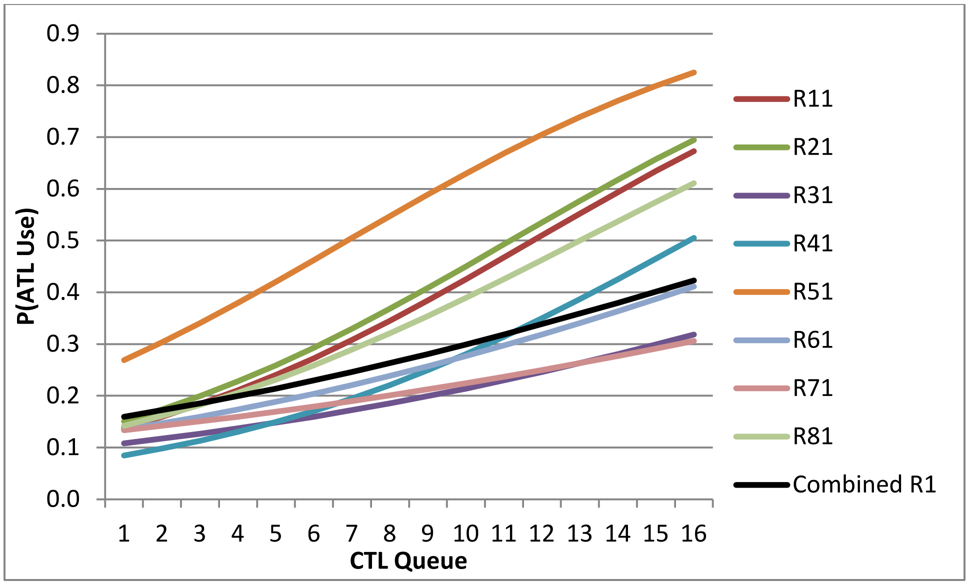

FIGURE D-1. Visualization of R1 Models

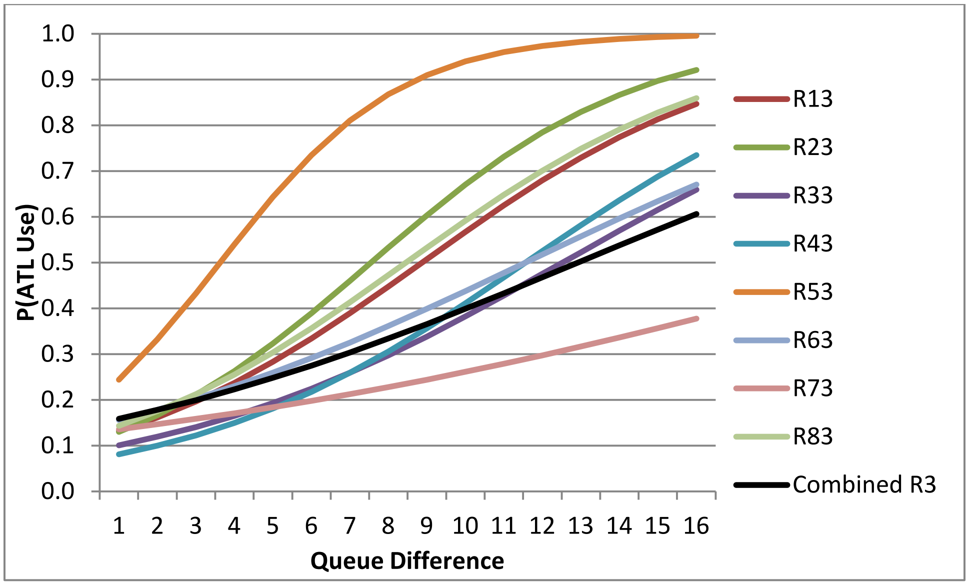

FIGURE D-2. Visualization of R3 Models

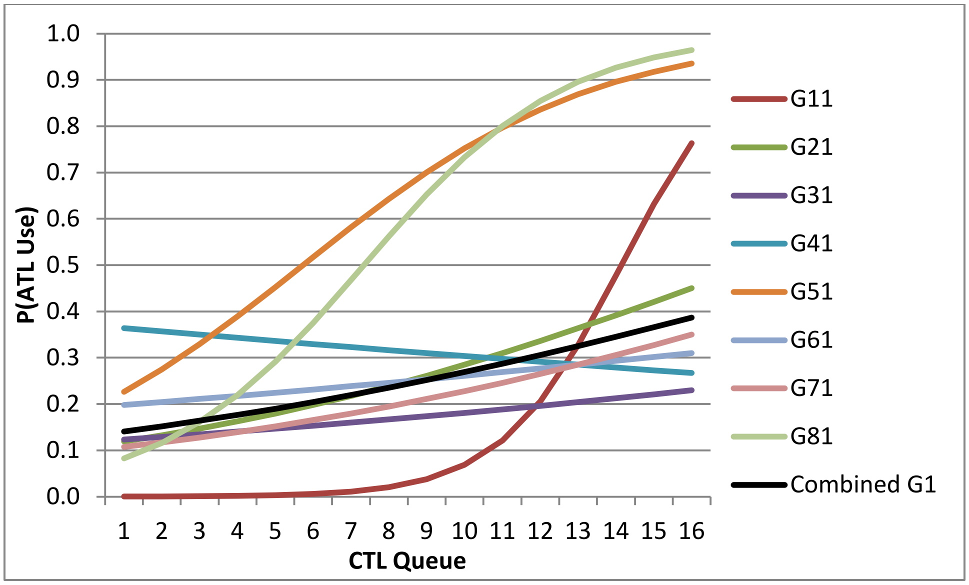

FIGURE D-3. Visualization of G1 Models

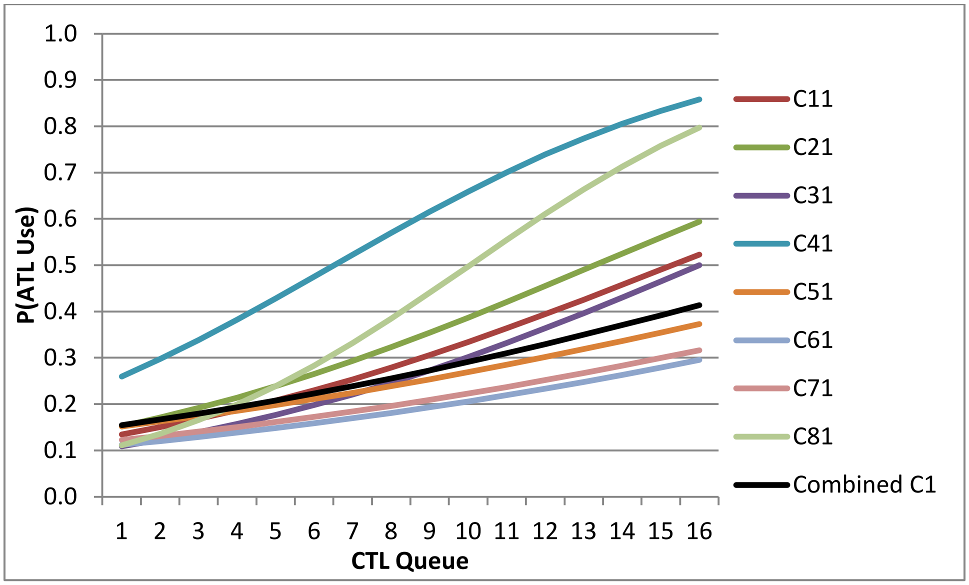

FIGURE D-4. Visualization of C1 Models

Site-by-Site Variability

The author examined site-by-site variability in the disaggregate models by computing the likelihood ratio test statistic for two comparisons:

1. One line (no site-to-site differences) versus parallel lines (separate intercepts for each site).
2. Parallel lines versus separate lines (separate slopes for each site).

Table D-1 summarizes this procedure.

TABLE D-1. Summary of Likelihood Ratio Test for Site-to-Site Differences

Model	Site	-2 Log L				H_0: no site effect			H_0: parallel line for each site		
		one line	parallel lines	separate lines	sum	G^2	df	p-value	G^2	df	p-value
R1	1	2413.68	2348.887	209.637	2262.365	64.795	7	<0.001	86.522	7	<0.001
	2			315.494							
	3			239.798							
	4			252.296							
	5			259.426							
	6			336.408							
	7			346.683							
	8			302.623							
R2	1	2397.06	2321.763	287.655	2302.043	75.293	6	<0.001	19.720	14	0.139
	2			304.323							
	3			235.408							
	4			245.408							
	5			251.760							
	6			333.455							
	7			345.549							
	8			298.485							
R3	1	2397.06	2322.031	287.824	2307.484	75.025	7	<0.001	14.547	7	0.042
	2			304.424							
	3			236.562							
	4			246.764							
	5			253.069							
	6			334.457							
	7			345.688							
	8			298.696							
G1	1	868.258	845.348	74.016	826.935	22.91	7	0.002	18.413	7	0.010
	2			72.630							
	3			63.008							
	4			51.006							
	5			66.970							
	6			70.025							
	7			177.537							
	8			251.743							
G2	1	863.679	839.012	73.884	806.957	24.667	6	<0.001	32.055	14	0.004
	2			69.968							
	3			50.765							
	4			50.996							

	5			66.646							
	6			69.688							
	7			175.109							
	8			249.901							
G3	1	884.180	849.672	74.121	839.607	34.508	7	<0.001	10.065	7	0.185
	2			74.217							
	3			61.962							
	4			52.278							
	5			65.562							
	6			69.151							
	7			182.265							
	8			260.051							
C1	1	3284.01	3206.59	373.051	3194.114	77.418	7	<0.001	12.476	7	0.086
	2			388.592							
	3			308.807							
	4			524.689							
	5			305.118							
	6			559.221							
	7			326.611							
	8			408.025							
C2	1	3264.20	3172.742	369.875	3139.280	91.456	6	<0.001	33.462	14	0.002
	2			374.955							
	3			293.682							
	4			521.891							
	5			300.827							
	6			553.508							
	7			320.235							
	8			404.307							
C3	1	3337.51	3270.186	370.901	3249.693	67.321	7	<0.001	20.493	7	0.005
	2			397.452							
	3			315.888							
	4			529.327							
	5			311.140							
	6			582.398							
	7			329.781							
	8			412.806							

The table indicates that differences among the sites necessitate separate intercepts for each of the models, as indicated by the very low p-values in the test for site effect. However, there was not enough site-to-site variability to necessitate separate slopes for each site in every model. Models R2, G3, and C1 appeared to consist of parallel lines for each site, while the other models had at least one site with a separate slope, as indicated by the low p-values in the test for parallel lines.

E MODEL COMPARISON DETAILS

This appendix contains a description of all data relationships related to the comparison of the aggregate and disaggregate models not contained within the body of Chapter 5. The author's intent is to provide the critical information relating to the contributions of Chapters 5 within the text of that chapter. However, in order for this research to be reproducible, this appendix provides all models and figures not contained within the results or discussion of Chapter 5.

Model Comparison with Absolute Difference Paired t-test

The comparison of the aggregate and disaggregate models with either other and with the observed field data is contained in Section 5.4, but this test considers the algebraic difference in values of the comparison data. In other words, the mean difference |d-bar| is indeed the average of the differences in each of the 65 pairs of field-observed or model predicted 15-minute intervals. This allows for large differences in opposite directions to essentially cancel out. If the absolute value of each paired difference is used, then the test becomes much more stringent, as displayed in Table E-1.

TABLE E-1. Comparison of Models and Field Data (Absolute Paired Differences)

H_0: Aggregate and Disaggregate Models (R3 / G1) are the same*		H_0: Disaggregate Model and Field Observations are the same*		H_0: Aggregate Model and Field Observations are the same*	
|d-bar|	15.0	|d-bar|	21.5	|d-bar|	15.1
s^2	194.4	s^2	373.8	s^2	165.8
n	65	n	65	n	65
test stat	8.68	test stat	8.98	test stat	9.43
df	64	df	64	df	64
p-value	<0.001	p-value	<0.001	p-value	<0.001
result	Reject	result	Reject	result	Reject
*Avg. ATL Flow (vph) of all 65 15-min intervals: Field = 98.1, Aggregate = 98.1, Disaggregate = 94.3					

Thus, if the absolute difference is used, then each of the tests rejects the null hypothesis, indicating that all model / field observations are statistically different.

Sensitivity Analysis for Model Comparison

Section 5.4.1 discusses the sensitivity of the disaggregate model to changes in input data such as through-movement demand, X_T, and right turns. This appendix contains a series of plots that support the author's findings that the difference between the aggregate and disaggregate model predictions is not sensitive to high or low values of these input data. Figure E-1 displays the difference in model predictions (aggregate minus disaggregate) against the total through-movement flow for each of the 65 15-minute intervals in the calibration database. The figure suggests that the difference between the predicted ATL flows is not related to the total through-movement flow.

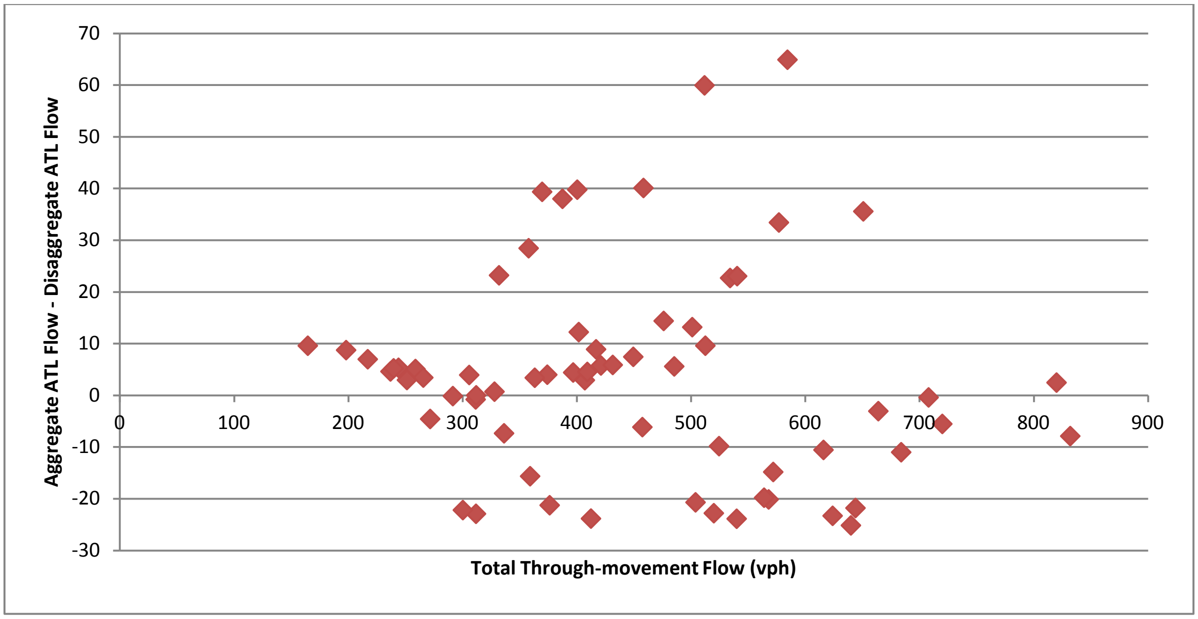

FIGURE E-1. Aggregate/Disaggregate Model Prediction Difference versus Total Through-movement Flow

When the difference in model predictions is plotted against X_T, a moderately-strong quadratic relationship becomes apparent (Figure E-2), although the author notes that the vast majority of the data points experienced a difference of less than 25 ATL vph, which is negligible over an hourly interval. However, the plot suggests that the aggregate model will predict significantly higher ATL flows for high values of X_T (only a few of which were observed in the dataset), which is intuitive in that the aggregate model is highly sensitive to changes in signal timing, which affects X_T.

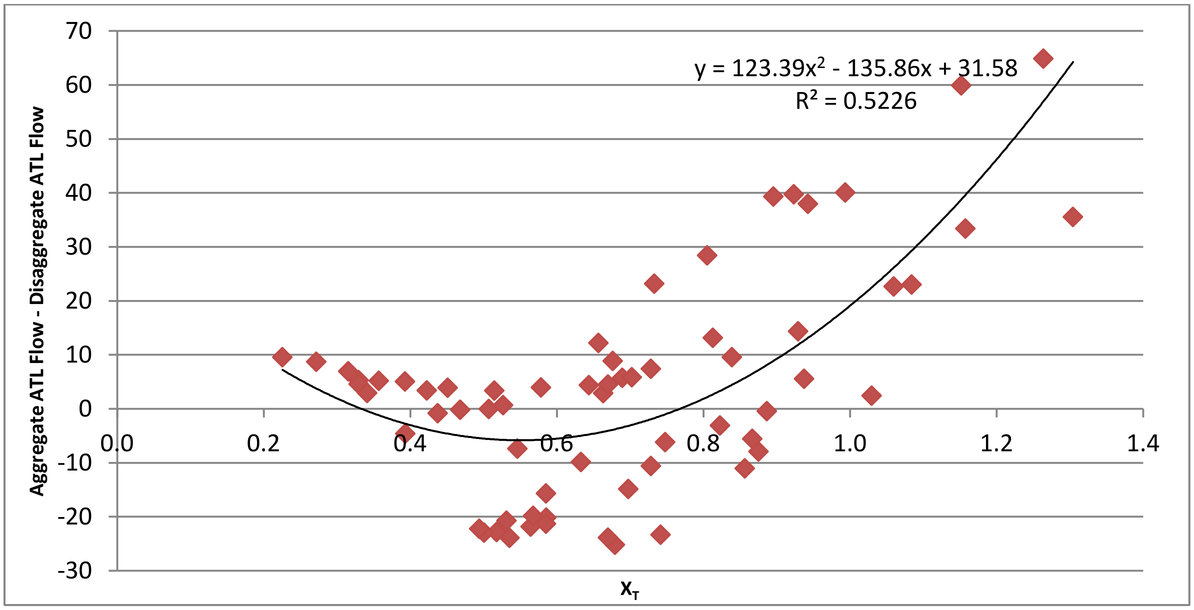

FIGURE E-2. Aggregate/Disaggregate Model Prediction Difference versus X_T

Figure E-3 displays the same plot but with X_R as the abscissa. Like the relationship displayed in Figure 5-4, the aggregate model predicts a lower ATL flow than the disaggregate model as the number of right turns increases, but (for data points with $X_R > 0$), these differences also appear to be relatively small (less than 25 ATL vph).

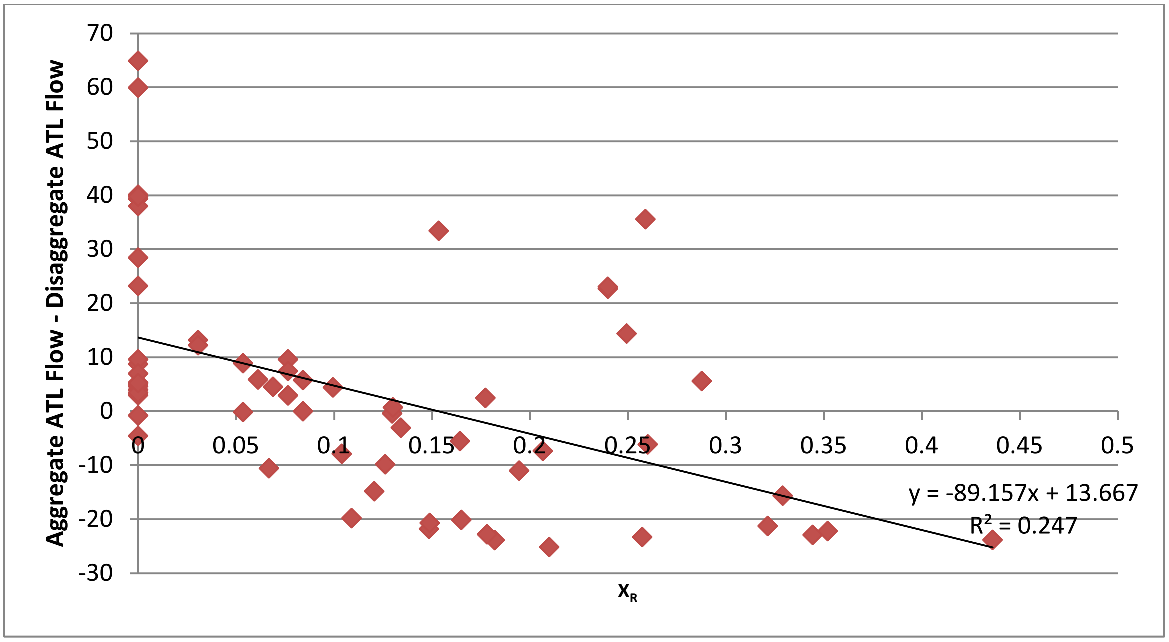

FIGURE E-3. Aggregate/Disaggregate Model Prediction Difference versus X_R

Variability in Simulation Algorithm

The author repeated 50 simulation runs to achieve an appropriate output ATL flow for the disaggregate model in order to compare the model predictions with the aggregate model results. Table E-2 gives the resulting average and standard deviation of the 50 simulation runs for each of the 65 15-minute intervals in the comparison dataset. The table indicates that the simulation runs for some of the data points were highly variable, but most of the data points had a standard deviation of under 20 ATL vph.

TABLE E-2. Summary of 50 Simulation Runs for Disaggregate Model

Approach	Data Point #	Field-observed ATL Flow (vph)	Aggregate Model ATL Flow (vph)	Simulated (Disaggregate Model) ATL Flow (vph)	
				Average	Standard Deviation
NB Garrett	1	42.2	43.2	34.5	12.4
NB Garrett	2	47.1	61.9	58.0	15.5
NB Garrett	3	48.6	80.1	76.1	14.7
NB Garrett	4	44.0	55.0	59.5	57.7
NB Garrett	5	85.7	72.0	68.6	15.3
NB Garrett	6	51.4	48.8	43.4	11.3
NB Garrett	7	49.9	48.5	43.8	11.3
NB Garrett	8	25.3	39.7	30.1	12.3
NB Garrett	9	34.1	49.9	47.0	13.2
SB Garrett	1	49.1	46.7	39.7	13.6
SB Garrett	2	74.2	61.0	61.8	15.6
SB Garrett	3	70.6	54.3	49.2	10.6
SB Garrett	4	41.2	57.2	53.8	13.7
SB Garrett	5	59.9	50.6	45.4	13.1
NB La Canada	1	80.4	88.3	98.2	20.5
NB La Canada	2	84.0	116.9	127.4	23.5
NB La Canada	3	112.0	102.7	117.5	20.1
NB La Canada	4	124.0	132.1	135.1	20.8
NB La Canada	5	204.0	190.1	187.6	27.0
NB La Canada	6	132.0	135.2	146.2	23.0
NB La Canada	7	116.0	149.6	150.0	25.2
NB La Canada	8	168.0	167.2	175.1	22.3
NB La Canada	9	156.0	144.4	149.9	21.9
SB La Canada	1	88.0	90.5	112.2	19.8
SB La Canada	2	100.0	72.9	96.7	19.5
SB La Canada	3	124.0	99.7	124.9	25.0
SB La Canada	4	128.0	103.1	126.4	23.3
SB La Canada	5	56.0	69.3	92.1	18.4
SB La Canada	6	84.0	83.2	103.3	19.9
SB La Canada	7	80.0	71.9	92.6	20.1
SB La Canada	8	152.0	85.5	105.3	20.1
EB Magee	1	64.0	60.6	60.6	12.3
EB Magee	2	52.6	59.6	58.9	13.5
EB Magee	3	79.8	86.9	83.9	22.7
EB Magee	4	107.3	123.7	114.1	21.3
EB Magee	5	60.7	58.1	58.2	13.0
EB Magee	6	79.5	91.0	85.2	18.5
EB Magee	7	76.3	99.8	92.3	24.0
EB Magee	8	88.2	81.4	77.0	16.4
EB Magee	9	67.5	88.6	84.1	16.8
EB Magee	10	72.2	122.1	108.9	19.5
EB Magee	11	99.4	89.6	77.4	16.8
EB Magee	12	68.2	91.5	82.6	17.9
EB Magee	13	71.9	95.7	89.8	20.3
WB Magee	1	56.1	56.5	80.3	19.5
WB Magee	2	59.7	87.3	93.4	19.0
WB Magee	3	63.9	50.9	66.6	17.2
WB Magee	4	56.1	55.6	62.9	17.1
WB Magee	5	62.7	52.7	74.0	17.6
WB Magee	6	36.4	36.9	59.8	13.0
WB Magee	7	27.7	34.9	57.1	13.8
EB Walker	1	122.1	112.2	83.8	19.3

EB Walker	2	120.7	98.8	75.6	21.3
EB Walker	3	144.0	129.3	89.9	19.7
EB Walker	4	166.6	139.7	101.7	21.7
EB Walker	5	237.2	232.3	167.4	34.8
EB Walker	6	185.0	155.6	115.5	19.1
EB Walker	7	224.2	196.4	136.4	27.1
EB Walker	8	161.0	136.8	97.0	22.6
WB Walker	1	150.3	122.1	107.7	23.6
WB Walker	2	178.8	190.7	157.3	25.7
WB Walker	3	114.0	121.1	115.5	21.4
WB Walker	4	156.2	155.8	133.1	26.6
WB Walker	5	170.7	161.9	138.9	28.4
WB Walker	6	183.1	228.0	192.4	35.1