For office use only
T1 ____________
T2 ____________
T3 ____________
T4 ____________

Team Control Number
816

Problem Chosen
B

For office use only
F1 ____________
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2005 Mathematical Contest in Modeling (MCM) Summary Sheet
(Attach a copy of this page to each copy of your solution paper.)

Type a summary of your results on this page. Do not include the name of your school, advisor, or team members on this page.

As analysts for a major transportation consulting firm we were tasked with exploring how traffic interacts in a large toll collection plaza. Specifically, we assessed the current configuration of the Ft. McHenry Toll Plaza on I-95. Our first goal was to determine the minimum number of tollbooths required from such a plaza. Secondly, we evaluated the worthiness of operating only as many tollbooths as incoming lanes of traffic.

We developed one primary stochastic model, using a series of M/M/1 queues and adjusting for vehicular movement, to estimate the optimal number of tollbooths for Ft. McHenry Plaza and extended the model to consider a worst-case scenario for traffic processing. We incorporated a Poisson distribution to model the possibility that we have both an unexpectedly large number of vehicles arriving and that our servers in the tollbooths happen to be having a particularly slow day. Not surprisingly, our model suggested increasing the number of servers to accommodate the demand. Clearly, this cannot be expanded indefinitely without consideration for the downstream flow of traffic so we incorporated a maximal-flow model to determine a cap on the number of tollbooths that may be deployed.

To obtain an optimum number of peak-hour booths we created a recursive model in Excel that accounted not only for uncertainty in the peak hour but also in the surrounding hours. We determined that during peak hour Ft. McHenry Plaza is under-equipped. Presently the Plaza has a maximum of 12 operational booths per direction of traffic. By extending this to 19 booths, driver times could be reduced during peak hours, even with the added merge congestion. At peak times the total drive time would be 8 minutes from the time the driver begins to decelerate to the time the driver merges from the tollgates and accelerates to full cruise speed.

Introduction:

Cars progressing through a toll plaza create a unique set of traffic problems for city planners and drivers. Toll plazas slow traffic on a busy road, especially when they require stopping at a barrier to pay an attendant. Moreover, the different types of payments and the different behavior of drivers add an element of variance to the time necessary to pay.

The primary focus of our tollbooth study is on the number of tollbooths required and queues that form from them. We examine the formation of queues when tollbooths become saturated, taking into consideration the flow balance required to successfully merge traffic after the plaza and send it downstream. Then we apply our findings to the Ft. McHenry toll plaza on I-95, one of the busiest in North America.

Our approach is simply stated, if the average number of cars processed per hour is greater than the incoming volume, queues will rapidly form based on the Poisson arrival and exponential service times. The most common way to compensate for resultant exponential growth of queue length is to fan upstream lanes into many queues. Unfortunately, at some point, the benefits gained from adding one more tollbooth are outweighed by the cost of merging the toll lanes back into the original traffic lanes. This diminishing benefit is easy to visualize if twenty lanes are thought to merge back down to two. The resultant traffic backup would eventually impede the tollbooth processing and therefore negate the benefits gained.

In other words, the upper limit on the optimal number of tollbooths is related to the number of lanes of downstream traffic. To find the optimal number of booths for a given road, therefore, requires information on traffic volume and the number of lanes of traffic.

While building our model, we found the maximum number of booths that could be used on a highway with n_2 lanes that fanned out to n_1 lanes, where $n_1 \geq n_2$, using an analogous fluid flow scenario. In one particular situation, we found that 4 lanes that are nearly always at maximum capacity should lead to about 19 tollbooths. However, the Ft. McHenry configuration has only 12. Our equations are based on the ratio of lanes converging together and the maximum capacity of the lanes at some cruise speed, which was obtained from the Highway Capacity Manual of 1998. Our deterministic model aptly fits empirical findings, but we found no conclusive way to deal with many of the complexities of fanning out or merging.

Next, we modeled traffic movement with a series of M/M/1 queues, but since the standard model does not consider the travel speeds involved, we made a model for the speed adjustments as the vehicles move, incorporating, braking distance, acceleration and deceleration, and the traffic density.

With the models finished, we determined that the optimal number of booths is dependent on arrival volume and maximum road capacity.. The number of booths in operation should vary throughout the day.. We also determined that the use of one booth per lane is rarely efficient. Instead, we purpose dynamic scheduling of booths, involving $n_1 \geq n_2$ lanes. Moreover, we give two scenarios, each showing when it is efficient to use one booth per lane and another showing when it is not, but it is almost always necessary to allow more booths per lane, enabling a greater ratio of toll lanes than incoming lanes.

There are many ways to optimize the flow of traffic at a toll plaza. We decided that if we minimize the amount of time a given driver spends in our system subject to the flow constraints of the system it would account for many possible definitions of optimal. For our purposes , optimal is defined as the number of booths necessary to minimize the amount of time required for one vehicle to progress through the entire process from entering the toll plaza at a cruising speed to exiting the toll plaza and regaining the cruising speed. This definition of optimal was chosen against alternatives such as cost to build, or pollution created because we think it encompasses many of the other possible definitions. For instance, the cost of building one new tollbooth is not significant in terms of the entire highway and plaza project. Furthermore, superfluous built-in but not staffed capacity is prudent whereas losing customers due to excessive waits is costly.

The Deterministic and Stochastic Model

Deterministic models are highly effective because they can be broadly applied. We found that our deterministic descriptions of the physical system under study can be used as a basis for many extensions.

Our model uses a series of M/M/1 queues, each one corresponding to a single toll lane. Moreover, the arrival volume has a Poisson distribution and the service time has an exponential distribution:

To model the portion of the transit time up to accelerating away from the tollbooth we split the time into four parts:

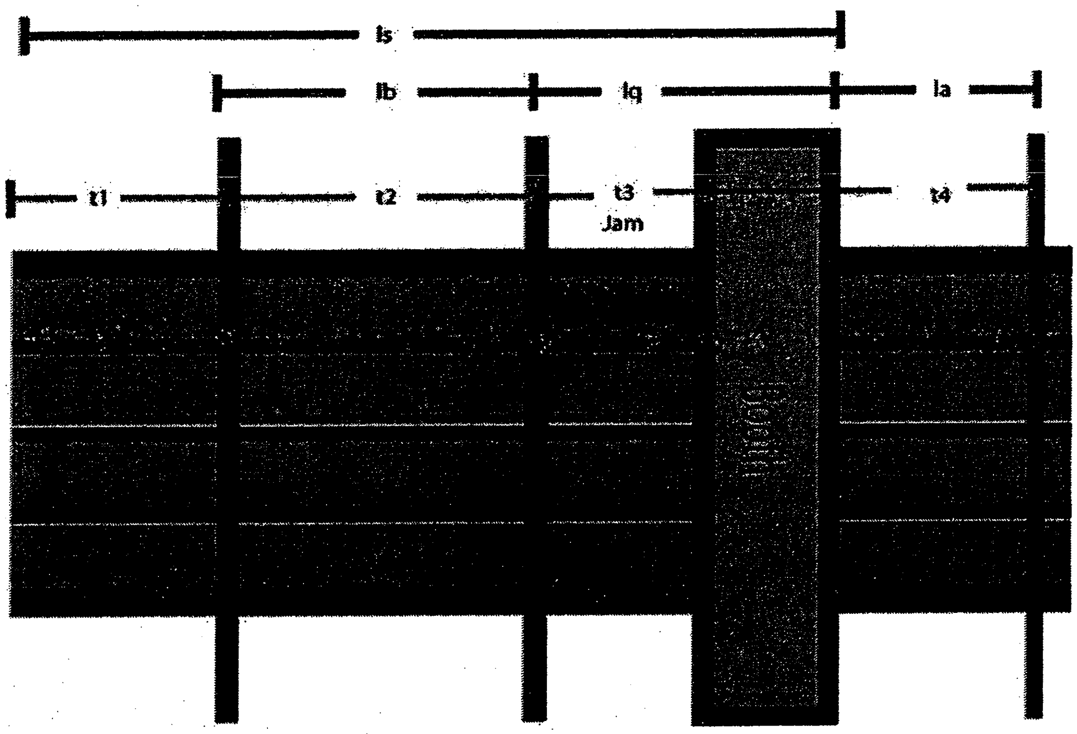
1. t_1 - Approaching the plaza at the cruising speed
2. t_2 - Breaking to the jam velocity
3. t_3 - Time spent at the jam velocity in the queue including the time spent to pay the toll
4. t_4 - Accelerating away from the tollbooth and merging to reduce number of continuing lanes to that before entering toll plaza.

Then total time a driver spends in the toll plaza is given by:

5. $t_s = t_1 + t_2 + t_3 + t_4$

The times in specific areas can be visualized in figure 1.

Fig 1.



The first portion of the model is the time spent after passing the reduce speed sign and approaching the toll plaza at the cruising velocity (u_c). The time spent at this speed, however is dependent on the length of the queue (l_q) and the length of roadway spent braking (l_b) both in meters. Finally, given the total distance from the reduce speed sign to the tollbooth (l_s) we can represent t_1 as:

$$6.\quad t_1 = \frac{(l_s - l_b - l_q)}{u_c}$$

Next, given the jam velocity (u_j) and the deceleration rate (d) the second segment can be represented as:

$$7.\quad t_2 = \frac{(u_c - u_j)}{d}$$

Finally, we can represent the final time segment before the leaving the tollbooth as:

8. $t_3 = \frac{l_q}{u_j}$

The key variable for the above equations is the length of the queue (l_q). We first estimated the number of cars in the queue, including the cars currently being serviced, (N_{q+s}) by using expected queue length plus the number being serviced of a Poisson distribution:

9. $N_{q+s} = \frac{\rho}{1-\rho}$

Given the number of lanes (n_1), we scaled length of the queue up by the length of the average vehicle and average space between vehicles, such as when they are closely spaced during arrival to the booths (s_j) to get the following identity:

10. $l_q = s_j N_{q+s}$

Contrasting our Model with a Currently Established Model:

Realizing the shortcomings of our estimation of the number of cars in the queue and the length of the queue we went to the literature and found some more nuanced identities (Saka and Agboh, 2002).

Their equations and parameters:

11.

$$N_q = (450T)\left\{(v/c) - 1 + \left[\frac{(v/c-1)^2 + [(3600n_1/c)(v/c)]}{150T}\right]^{0.5}\right\}(c/3600n_1)$$

12. $l_q = l_{toll} + [s_j N_q - (l_{toll})](n_1/n_2)$, for $l_{toll} \le s_j N_q$

13. $s_j N_q$, for $l_{toll} \ge s_j N_q$

Where:

N_q	Total number of vehicles in the queue per lane at the toll plaza
T	Analysis period (h)
v	Arrival volume (vph)
c	Hourly throughput (vph)
l_q	Length of queue at the toll plaza (m)
l_{toll}	Length of toll service lanes
s_j	$1000/k_j$
k_j	Jam density (veh./km)
n_1	Number of toll service lanes
n_2	Number of upstream mainline traffic lanes

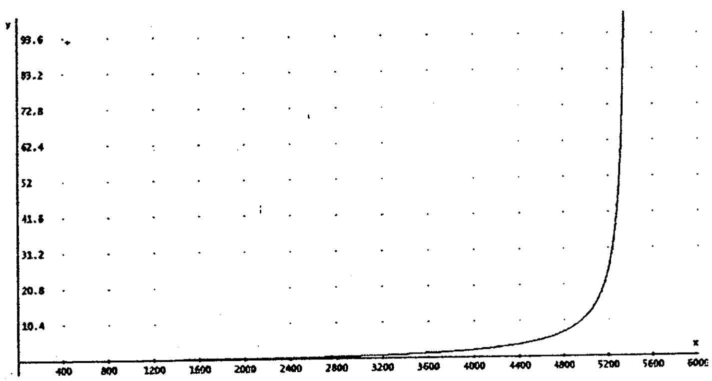
To illustrate the differences and shortcomings of our model, we will examine two different scenarios.

Arrival Volume:	4500 veh/hr	6500 veh/hr
Processing Rate:	450 veh/hr	450 veh/hr
Number of Lanes:	12	12
Our Expected Queue Length.	5 veh	–5.9 veh

Their Expected Queue Length	5.7 veh	29.7 veh

Thus, we can see that there are clear limitations to our model. For instance, our model breaks when the average arrival volume exceeds or is equal to the average processing rate (see fig. 2), which is consistent with M/M/1 queues, but their model allows for added volume. In order to avoid that problem, we'll use an average arrival rate that is less than or equal to the average processing rate.

Fig. 2 – Queue growth as a function of arrival volume



Next, we'll examine a typical day with a heavy morning rush hour and light evening rush hour. We began by locating our parameters, focusing on places that experience a heavy volume and utilize many tollbooths. In particular, we used traffic movement parameters and toll booth processing rates of the south bound lanes of the Fort McHenry Toll Plaza on I-95, but a typical day of traffic flow was not given, so we had to tabulate our own data and fit it to a scenario with dual peaks. Below are the "calibrated and validated parameter values" of the toll plaza (Saka and Agboh, 2002).

u_c	$25 m/s$
u_j	$11 m/s$
k_j	$.96 veh/m$
s_j	10 m
a, a_j	$1.5 m/s^2$, $.25 m/s^2$
d, d_j	$4.5 m/s^2$, $1.0 m/s^2$
c	450 vphpl

(Saka and Agboh, 2002)

Extending the Model: A Maximal Flow Method for Constraining Fanning

Our deterministic model would suggest that we may indefinitely add tollbooths to accommodate increases in traffic. Each time saturation reaches 100%, e.g. $v/(c \cdot n_1) = 1$ we simply increase n_1 to process 450 more drivers per hour. Intuitively this is not the case. It is clear that at some point the output from additional booths will create difficulty for cars that are merging with downstream traffic after leaving the tollbooths. The Highway Capacity Manual (TRB, 68) suggests that in order to measure the effectiveness of a proposed roadway the flow, in passenger cars per hour per lane (pcphpl), should be calculated and compared to standards for roadways of that type. The Manual describes free-flow speed under ideal conditions as the mean speed of passenger cars under low to moderate flow. On a 4 lane highway, this should be a speed of at least 100kph with 2,200 pcphpl.

Upon examining our upstream roadway at time t_1 we find it has free flow capacity:

14. $f_c = v/n_2 = 2200$ (arrival volume / # of lanes upstream traffic)

Since we know that our tollbooths have a mean processing rate of 450 pcph, we can find a maximum number of booths that may be utilized. Once traffic has split into n_1 tollbooth lanes it must merge back into n_2 lanes to some cruise velocity (u_c).

We restate the following definitions:

n_1	Number of tollbooth lanes (l)
n_2	Number of lanes leading prior to following the tollbooth lanes (l)
v	Average Arrival volume (vph)
c	Average Processing Volume per Tollbooth (vphpl)
$\rho = \frac{v}{n_1 c}$	Utilization
$f_c = \frac{v}{n_2}$	Average Arrival Volume at Cruise Speed per pre toll lanes (vphpl)

Now consider the variable:

$$S_{through} = \begin{cases} \frac{v}{cn_1} & if \quad v \le cn_1 \\ 1 & if \quad v > cn_1 \end{cases}$$

$S_{through}$ is the saturation percentage through the booths, making the flow through a single booth the product of the saturation percentage and the average processing rate:

15. $f_b = c * S_{through}$

Now we can derive the theoretical maximum allowed booths for a four lane freeway.

$$\frac{n_1}{n_2} f_b \le f_c$$

16. $\Downarrow$

$$n_1 \le \frac{f_c n_2}{f_b}$$

Note that this provides a maximum number of booths that can be used with any such freeway system.

Applications of the Model:

Using equation 16 we can see that the Ft. McHenry Tunnel Tollway is constrained by the number of booths available. The tollbooth plaza only operates a maximum of 12 tollbooths. However, this restricts flow to $12 * 450 = 5400$ vph or $5400/4 = 1350$ pvphpl.

We saw above that this freeway should be able to have a flow of 2,200 pvphpl. A severe queue forms when the tollbooth is oversaturated, which would be the case if the I-95 were operating at full capacity. Equation 16 also implies that at full capacity of 2,200 pvphpl we would need at least 19.555 tollbooths to prevent over-saturation.

We used Excel to model both situations. We broke the day into 48 discrete time intervals, as seen in figure 3, using information on peak operating conditions from Saka and Agboh.

Fig. 3

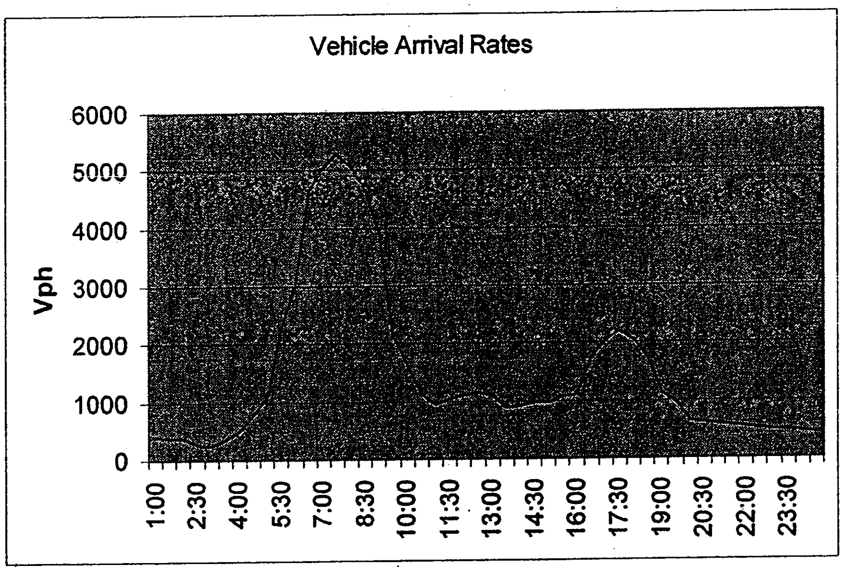


Figure one shows typical vehicle arrivals under present conditions. Our model (which can be found in appendix A) shows that

Next, we determined the expected queue lengths for the above arrival volumes, and since we were within equation 16's maximum output volume, we saw no significant reason to employ a any sort of static booth setup. Instead, a dynamic scheduling of booths would prevent underutilization and is entirely possible via shift labor. For instance, we had to find the minimum number of booths to employ to prevent an exponentially growing queue from going out of control, so used exactly 12 booths throughout the day, which prevents extreme backups during the first rush hour. However, throughout most of the day, queues are nearly negligible, showing that it is inefficient to employ a set amount of booths throughout the day. We purpose that a small number of booths be employed during non-peak hours, and during peak hours, employ additional booths.

Next, we'll demonstrate the drawbacks of static booth scheduling below:

Fig. 4

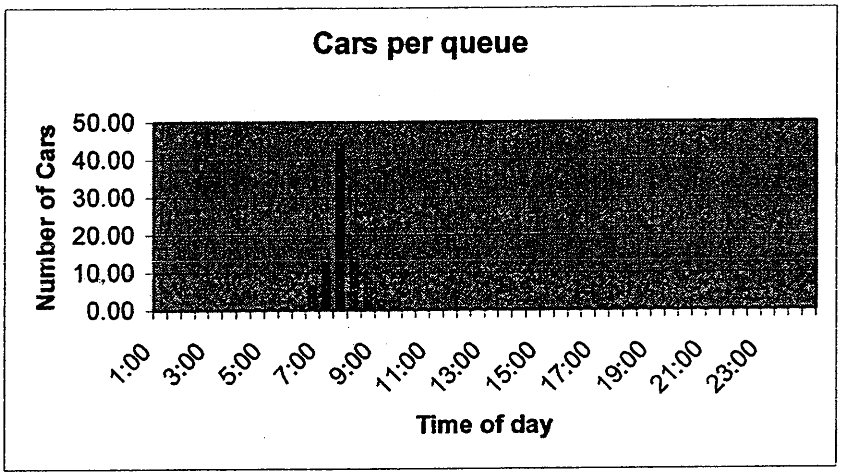


Figure two shows the extreme underutilization of the booth resources.

Fig. 5

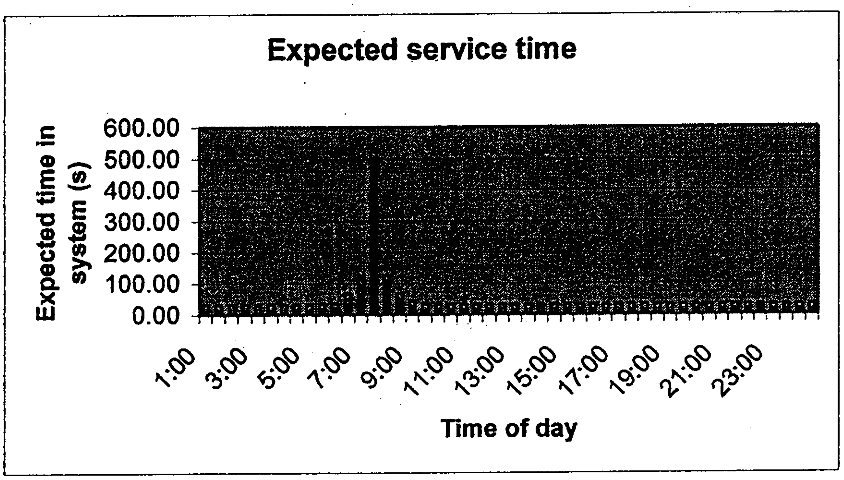


Figure three shows the nearly minimal time that the average car spends in the entire system, as described by equation four.

Overall, so long as we stay within the limits purposed by equation 16, a dynamic scheduling of booths is far superior to a static ratio of booths to originating lanes. Likewise, from equation 16 we can determine the peak output of any set of tollbooths since the maximum safe flow established for average roads cannot be surpassed. With the maximum number of booths determined, we can then work backwards, focusing on the typical daily traffic volume. Next, we need to choose a reasonable acceptable queue or an average acceptable amount of time for any car to have to spend in the system.

From equation nine, or more importantly, equation 5, we can generate the average waiting times and queue lengths for any typical day. Instead of employing a set amount of booths throughout the day, we vary the number of booths open throughout the day to minimize company costs and the amount of time a customer spends in the system. Most importantly, we can predict the needed number of booths, constrained by both time and money.

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Appendix A | **Team Control #816**

Time	Start Values	1:00	1:30	2:00	2:30	3:00	3:30
<u>Parameters</u>							
v(vph)	500	500	460	450	330	300	420
v(vph) transformed	406	406	374	366	268	244	341
v(vph) transformed	662	662	609	595	437	397	556
c(vph/booth)	450	450	450	450	450	450	450
n1(lanes)	12	12	12	12	12	12	12
n2(lanes)	4	4	4	4	4	4	4
kj(v/m)	0.96	0.96	0.96	0.96	0.96	0.96	0.96
Uc(m/s)	25	25	25	25	25	25	25
Uj(m/s)	1.3	1.3	1.3	1.3	1.3	1.3	1.3
a(m/s^2)	1.5	1.5	1.5	1.5	1.5	1.5	1.5
d(m/s^2)	4.5	4.5	4.5	4.5	4.5	4.5	4.5
sj	10	10	10	10	10	10	10
ls	310	310	310	310	310	310	310
l_toll	310	310	310	310	310	310	310
<u>Dependant Vars.</u>							
Nq	0.01	0.01	0.01	0.00	0.00	0.00	0.00
Ns	0.08	0.08	0.07	0.07	0.05	0.05	0.06
N	0.08	0.08	0.07	0.07	0.05	0.05	0.07
lb(m)	69.26	69.26	69.26	69.26	69.26	69.26	69.26
lq(m)	0.06	0.06	0.05	0.05	0.03	0.02	0.04
la(m)	208.33	208.33	208.33	208.33	208.33	208.33	208.33
t1	9.63	9.63	9.63	9.63	9.63	9.63	9.63
t2	5.27	5.27	5.27	5.27	5.27	5.27	5.27
t3	0.05	0.05	0.04	0.04	0.02	0.02	0.03
t4	16.67	16.67	16.67	16.67	16.67	16.67	16.67
t	31.61	31.61	31.60	31.60	31.58	31.58	31.59

Appendix A **Team Control #816**

4:00	4:30	5:00	5:30	6:00	6:30	7:00	7:30	8:00
600	950	1350	2800	3700	5700	6200	6500	6200
487	772	1097	2274	3006	4630	5036	5280	5036
794	1257	1786	3705	4895	7542	8203	8600	8203
450	450	450	450	450	450	450	450	450
12	12	12	12	12	12	12	12	12
4	4	4	4	4	4	4	4	4
0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
25	25	25	25	25	25	25	25	25
1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
10	10	10	10	10	10	10	10	10
310	310	310	310	310	310	310	310	310
310	310	310	310	310	310	310	310	310
0.01	0.02	0.05	0.31	0.70	5.16	12.92	43.02	12.92
0.09	0.14	0.20	0.42	0.56	0.86	0.93	0.98	0.93
0.10	0.17	0.25	0.73	1.26	6.01	13.85	44.00	13.85
69.26	69.26	69.26	69.26	69.26	69.26	69.26	69.26	69.26
0.09	0.24	0.52	3.07	6.99	51.57	129.15	670.67	129.15
208.33	208.33	208.33	208.33	208.33	208.33	208.33	208.33	208.33
9.63	9.62	9.61	9.51	9.35	7.57	4.46	-17.20	4.46
5.27	5.27	5.27	5.27	5.27	5.27	5.27	5.27	5.27
0.07	0.18	0.40	2.36	5.37	39.67	99.35	515.90	99.35
16.67	16.67	16.67	16.67	16.67	16.67	16.67	16.67	16.67
31.63	31.74	31.94	33.80	36.66	69.17	125.74	520.63	125.74

Appendix A **Team Control #816**

8:30	9:00	9:30	10:00	10:30	11:00	11:30	12:00	12:30
5700	4800	2600	2025	1400	1150	1290	1360	1420
4630	3899	2112	1645	1137	934	1048	1105	1153
7542	6351	3440	2679	1852	1522	1707	1799	1879
450	450	450	450	450	450	450	450	450
12	12	12	12	12	12	12	12	12
4	4	4	4	4	4	4	4	4
0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
25	25	25	25	25	25	25	25	25
1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
10	10	10	10	10	10	10	10	10
310	310	310	310	310	310	310	310	310
310	310	310	310	310	310	310	310	310
5.16	1.88	0.25	0.13	0.06	0.04	0.05	0.05	0.06
0.86	0.72	0.39	0.30	0.21	0.17	0.19	0.20	0.21
6.01	2.60	0.64	0.44	0.27	0.21	0.24	0.26	0.27
69.26	69.26	69.26	69.26	69.26	69.26	69.26	69.26	69.26
51.57	18.76	2.51	1.33	0.56	0.36	0.47	0.53	0.58
208.33	208.33	208.33	208.33	208.33	208.33	208.33	208.33	208.33
7.57	8.88	9.53	9.58	9.61	9.62	9.61	9.61	9.61
5.27	5.27	5.27	5.27	5.27	5.27	5.27	5.27	5.27
39.67	14.43	1.93	1.03	0.43	0.28	0.36	0.40	0.45
16.67	16.67	16.67	16.67	16.67	16.67	16.67	16.67	16.67
69.17	**45.24**	**33.40**	**32.54**	**31.97**	**31.83**	**31.90**	**31.95**	**31.99**

Appendix A

Team Control #816

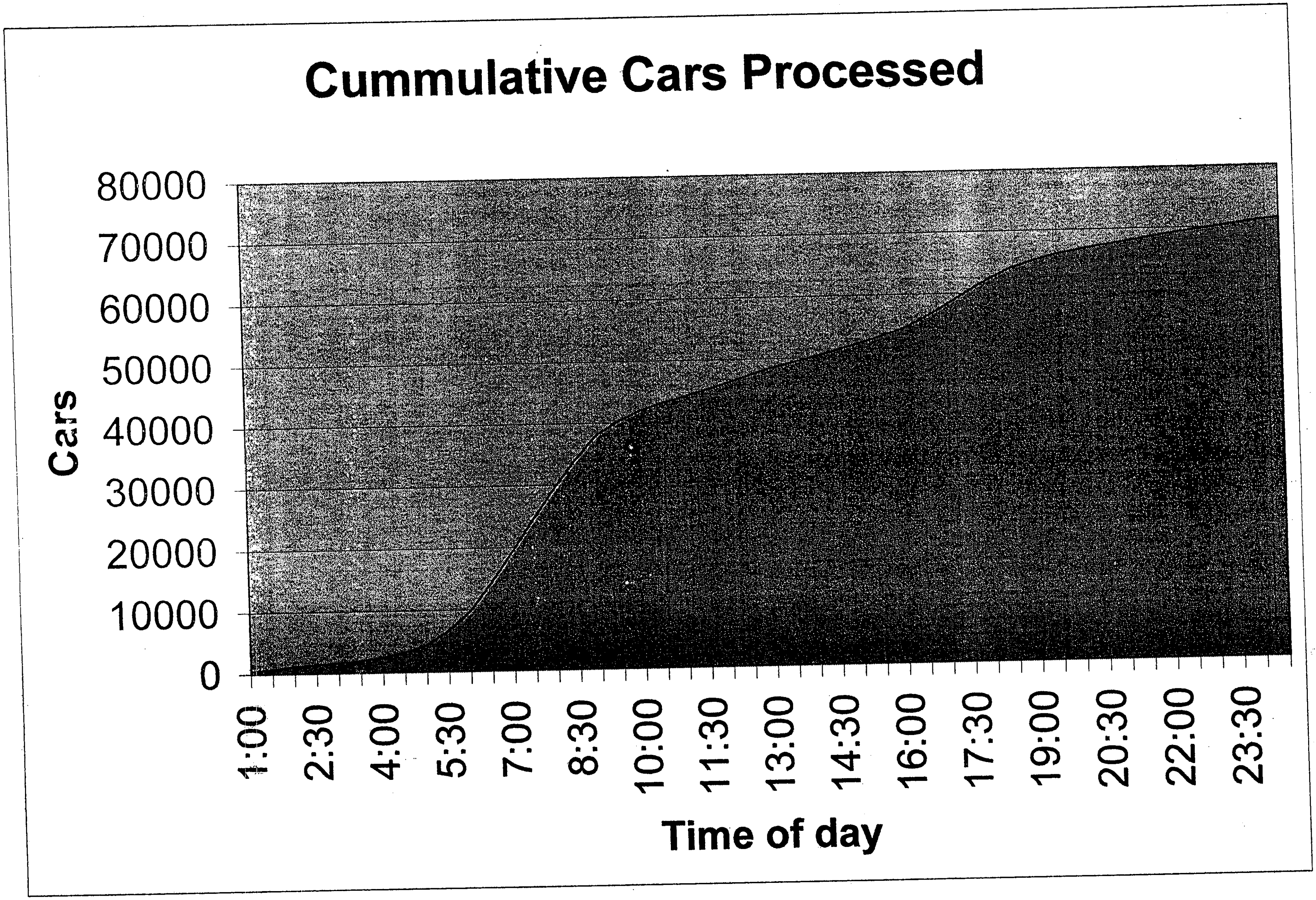
13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00
1350	1080	1120	1190	1200	1320	1350	2100	2500
1097	877	910	967	975	1072	1097	1706	2031
1786	1429	1482	1574	1588	1746	1786	2778	3308
450	450	450	450	450	450	450	450	450
12	12	12	12	12	12	12	12	12
4	4	4	4	4	4	4	4	4
0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
25	25	25	25	25	25	25	25	25
1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
10	10	10	10	10	10	10	10	10
310	310	310	310	310	310	310	310	310
310	310	310	310	310	310	310	310	310
0.05	0.03	0.03	0.04	0.04	0.05	0.05	0.15	0.23
0.20	0.16	0.17	0.18	0.18	0.20	0.20	0.32	0.38
0.25	0.19	0.20	0.22	0.22	0.25	0.25	0.46	0.60
69.26	69.26	69.26	69.26	69.26	69.26	69.26	69.26	69.26
0.52	0.32	0.34	0.39	0.40	0.49	0.52	1.46	2.27
208.33	208.33	208.33	208.33	208.33	208.33	208.33	208.33	208.33
9.61	9.62	9.62	9.61	9.61	9.61	9.61	9.57	9.54
5.27	5.27	5.27	5.27	5.27	5.27	5.27	5.27	5.27
0.40	0.24	0.26	0.30	0.31	0.38	0.40	1.12	1.74
16.67	16.67	16.67	16.67	16.67	16.67	16.67	16.67	16.67
31.94	31.79	31.81	31.85	31.85	31.92	31.94	32.63	33.22

Appendix A **Team Control #816**

17:30	18:00	18:30	19:00	19:30	20:00	20:30	21:00	21:30
2700	2500	2100	1400	1200	800	750	725	695
2193	2031	1706	1137	975	650	609	589	565
3572	3308	2778	1852	1588	1058	992	959	920
450	450	450	450	450	450	450	450	450
12	12	12	12	12	12	12	12	12
4	4	4	4	4	4	4	4	4
0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
25	25	25	25	25	25	25	25	25
1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
10	10	10	10	10	10	10	10	10
310	310	310	310	310	310	310	310	310
310	310	310	310	310	310	310	310	310
0.28	0.23	0.15	0.06	0.04	0.02	0.01	0.01	0.01
0.41	0.38	0.32	0.21	0.18	0.12	0.11	0.11	0.10
0.68	0.60	0.46	0.27	0.22	0.14	0.13	0.12	0.12
69.26	69.26	69.26	69.26	69.26	69.26	69.26	69.26	69.26
2.78	2.27	1.46	0.56	0.40	0.16	0.14	0.13	0.12
208.33	208.33	208.33	208.33	208.33	208.33	208.33	208.33	208.33
9.52	9.54	9.57	9.61	9.61	9.62	9.62	9.62	9.62
5.27	5.27	5.27	5.27	5.27	5.27	5.27	5.27	5.27
2.14	1.74	1.12	0.43	0.31	0.13	0.11	0.10	0.09
16.67	16.67	16.67	16.67	16.67	16.67	16.67	16.67	16.67
33.59	33.22	32.63	31.97	31.85	31.68	31.67	31.66	31.65

Appendix A **Team Control #816**

22:00	22:30	23:00	23:30	0:00	0:30
675	630	600	580	570	530
548	512	487	471	463	431
893	834	794	767	754	701
450	450	450	450	450	450
12	12	12	12	12	12
4	4	4	4	4	4
0.96	0.96	0.96	0.96	0.96	0.96
25	25	25	25	25	25
1.3	1.3	1.3	1.3	1.3	1.3
1.5	1.5	1.5	1.5	1.5	1.5
4.5	4.5	4.5	4.5	4.5	4.5
10	10	10	10	10	10
310	310	310	310	310	310
310	310	310	310	310	310
0.01	0.01	0.01	0.01	0.01	0.01
0.10	0.09	0.09	0.09	0.09	0.08
0.11	0.10	0.10	0.10	0.09	0.09
69.26	69.26	69.26	69.26	69.26	69.26
0.11	0.10	0.09	0.08	0.08	0.07
208.33	208.33	208.33	208.33	208.33	208.33
9.63	9.63	9.63	9.63	9.63	9.63
5.27	5.27	5.27	5.27	5.27	5.27
0.09	0.08	0.07	0.06	0.06	0.05
16.67	16.67	16.67	16.67	16.67	16.67
31.65	31.64	31.63	31.62	31.62	31.61


Cummulative Cars Processed
Cars
80000
70000
60000
50000
40000
30000
20000
10000
0
1:00
2:30
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5:30
7:00
8:30
10:00
11:30
13:00
14:30
16:00
17:30
19:00
20:30
22:00
23:30
Time of day