

4.0 Simulation Model

The most important goal for this project is to develop a simulation model for the peak hour operation, which is from 2pm to 6pm. However, our model runs from noon to 7pm. The reason we start earlier is because we should include a buffer period. That is, when the rush hour starts, there should already be some bus stops or storage spaces occupied. Our model includes three processes: bus loading, unloading, and bus staging. To help with the analysis, an event graph is provided to illustrate the bus operation process in the Transbay Terminal. A more detailed and technical description of the simulation is provided in the Appendices.

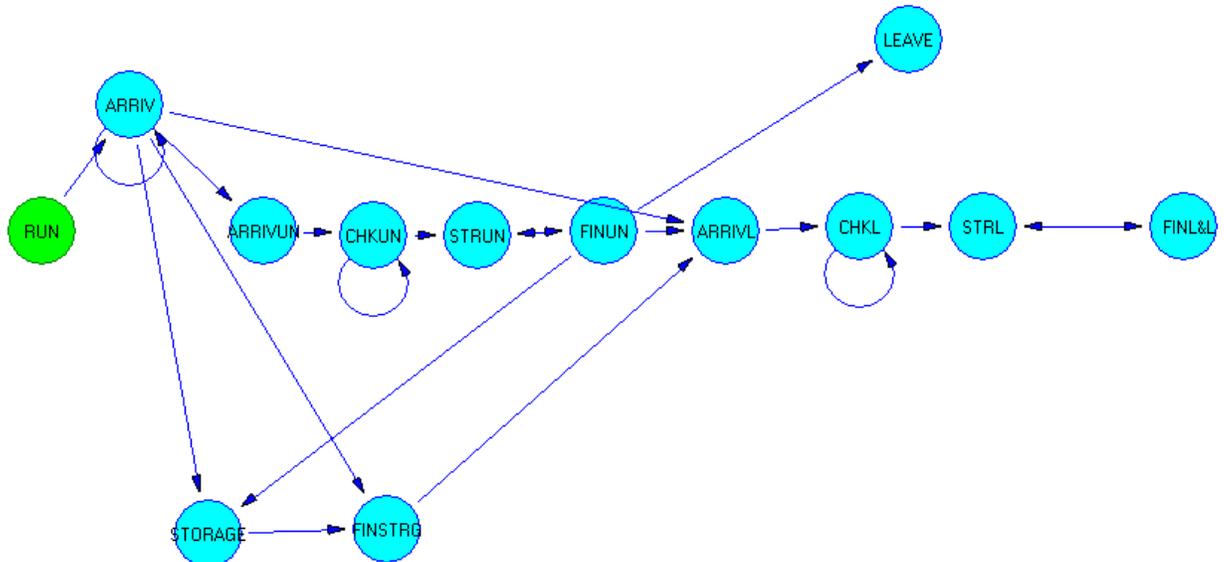


Figure 11: Event Graph in Sigma

This event graph simulates the following 5 processes that may happen when a bus comes to terminal:

1. A bus unloads passengers and then leaves the terminal.
2. A bus unloads passengers, and then goes to storage place if it is more than 10 minutes before the scheduled leaving time after unloading; then it leaves storage before 10 minutes of scheduled departure time to begin its loading process.
3. A bus unloads passengers, and starts the loading process directly if its scheduled leaving time is within 10 minutes after unloading.
4. Empty buses from the East Bay will go to the storage right away if its scheduled leaving time is more than 10 minutes from the time it arrives and wait for its loading process.
5. Empty buses from the East Bay will start the loading process immediately if its scheduled leaving time is within 10 minutes.

This model simulates the afternoon peak operation based on the current schedule of AC Transbay service. There are 234 buses leaving the terminal during 12pm-7pm in a day. The input data file has related information of all buses, and each bus has 6 columns: number of unloading passengers, interarrival time, scheduled leaving time, assigned bus stop for loading, total loading time and an indicator specifying if the bus is the initial staging buses at noon. In this simulation, we can trace the number of bus in the storage at a specific time and index of a bus (the arriving order of a bus), and easily keep track of the state of a bus. For example, a bus that is scheduled to leave the terminal at 3pm arrives at 2pm. After unloading passengers, it goes to the storage at 2:05pm. Then, it comes out the storage at 2:50pm and starts loading process. Finally, it leaves the terminal at 3pm. Furthermore in our model, we already simulate out buses that coming from 12pm-7pm. However, we should also consider those arrive before 12pm, then enter the storage and wait for their afternoon loading process. By going through the detail Schedule Report provided by AC Transit, we find out that only three buses belong to this situation. Hence instead of starting our simulation from 12pm, we change the starting of our simulation from the first arrival of those three buses, and this allows our model to include all the buses that arrive and leave after 12pm.

One of our important assumptions is that we suppose all buses will arrive on time regardless of traffic condition. We do not consider the situation when buses arrive late/early to the terminal compared to scheduled arrival time since it is really hard for us to predict the traffic condition.

After running this model, we can get the result and do sensitivity analysis to test the alternative designs and configurations for feasibility and efficiency.

5.0 Sensitivity Analysis

5.1 Performance of the Unloading/loading Processes

One of our goals for this sensitivity analysis is to determine the optimal ahead-of-schedule leaving storage time (how long in advance a bus should leave the storage for loading). The second goal is to evaluate the impact of different number of bus stops and bus stop layout on the on time performance. After running the simulation, we convert the output file to excel format to compute the following six performance measurements. Based on these measurements, we can recommend the optimal decision matrix to the temporary system.

- a. Average Waiting Time to Load Passenger – for each bus, it is calculated by subtracting the time it starts to load by the time it arrives for loading. Then we take the average of all buses.
- b. Average Waiting Time to Unload – the computing process is similar to the above. It equals to the time it starts to unload minus the time it arrives for unloading. We get the individual result and then calculate the average value of them.
- c. Average Lateness – lateness for individual bus is the difference of its actual departure time and its scheduled departure time. We then calculate the average value among those buses, which are late.
- d. Percentage of Delayed Loading Process – the percentage of those buses which find its assigned bus stop occupied.

- e. Percentage of Delayed Unloading Process – the percentage of those buses that find the first bus stop occupied when it arrives.
- f. Percentage of Being Late for Departure: the percentage of those buses which leave later than its scheduled leaving time.

(Note: We’ve found the 93 percentile for the first three measurements. The pivot point separates the 7% highest value from the rest. The reason we use percentile is that what we care about the lateness is those data with high value. One minute late may not affect the on-time performance much. Hence, percentile may be more practical in evaluating the on-time performance. Due to the limit number of data, generating a regression to the data may not be possible. Consequently, we assume it reflects a normal distribution with probability of 93%, and z value is approximately 1.5. As a result, the 93 percentile is roughly equal to mean + 1.5 *standard derivation.)

Each table below summarizes one of the above six measurements with varying input variables.

Average Waiting Time to Load													
Ahead-of-Schedule Leaving Storage	5 Minutes (minutes)			10 Minutes (minutes)			15 Minutes (minutes)			20 Minutes (minutes)			
	AVE	STD	93 Percentile	AVE	STD	93 Percentile	AVE	STD	93 Percentile	AVE	STD	93 Percentile	
Based on Destination	15 Bus Stops	0.303	1.479	2.521	1.349	3.609	6.762	5.634	19.455	34.818	8.660	19.279	37.579
	16 Bus Stops	0.252	1.436	2.406	1.021	3.127	5.711	3.214	12.462	21.908	6.416	13.824	27.152
	17 Bus Stops	0.189	1.351	2.215	0.643	2.153	3.872	2.773	12.180	21.043	5.193	12.083	23.318
	18 Bus Stops	0.151	1.284	2.077	0.466	1.961	3.408	2.496	12.140	20.706	4.475	11.675	21.988
Based on Frequency	15 Bus Stops	0.265	1.188	2.046	0.983	0.204	1.289	2.193	4.439	8.851	5.748	9.795	20.440
	16 Bus Stops	0.303	1.578	2.670	1.017	3.153	5.746	3.176	12.458	21.864	6.416	13.827	27.156
	17 Bus Stops	0.239	1.503	2.494	0.618	2.143	3.832	2.735	12.175	20.997	5.193	12.086	23.323
	18 Bus Stops	0.202	1.444	2.368	0.454	1.954	3.385	2.496	12.140	20.706	4.487	11.675	22.000

Table 9: Average Waiting Time to Load

Average Waiting Time to Unload													
Schedule Leaving Storage	5 Minutes (minutes)			10 Minutes (minutes)			15 Minutes (minutes)			20 Minutes (minutes)			
	AVE	STD	93 Percentile	AVE	STD	93 Percentile	AVE	STD	93 Percentile	AVE	STD	93 Percentile	
Based on Destination	15 Bus Stops	0.049	0.102	0.202	0.102	0.178	0.369	0.196	0.260	0.587	0.245	0.3	0.695377014
	16 Bus Stops	0.049	0.102	0.202	0.109	0.185	0.387	0.186	0.229	0.530	0.221	0.2319	0.568729312
	17 Bus Stops	0.049	0.102	0.202	0.109	0.185	0.387	0.186	0.229	0.530	0.221	0.2319	0.568729312
	18 Bus Stops	0.049	0.102	0.202	0.109	0.185	0.387	0.186	0.229	0.530	0.221	0.2319	0.568729312
Based on Frequency	15 Bus Stops	0.018	0.068	0.120	0.054	2.880	4.374	0.211	0.490	0.946	0.263	0.6515	1.240444473
	16 Bus Stops	0.014	0.052	0.091	0.060	0.000	0.060	0.084	0.160	0.324	0.109	0.2107	0.424737073
	17 Bus Stops	0.014	0.052	0.091	0.060	0.131	0.256	0.084	0.160	0.324	0.109	0.2107	0.424737073
	18 Bus Stops	0.014	0.052	0.091	0.063	0.142	0.276	0.102	0.200	0.402	0.126	0.2349	0.478626087

Table 10: Average Waiting Time to Unload

Average Lateness													
Ahead-of-Schedule Leaving Storage Time	5 Minutes (minutes)			10 Minutes (minutes)			15 Minutes (minutes)			20 Minutes (minutes)			
	AVE	STD	93 Percentile	AVE	STD	93 Percentile	AVE	STD	93 Percentile	AVE	STD	93 Percentile	
Based on Destination	15 Bus Stops	0.992	1.923	3.875	0.592	2.672	4.600	3.782	17.747	30.402	4.608	16.292	29.04674388
	16 Bus Stops	0.950	1.922	3.832	0.433	2.590	4.319	1.655	11.211	18.472	2.798	10.964	19.24452604
	17 Bus Stops	0.887	1.845	3.654	0.256	1.632	2.705	1.433	11.024	17.969	1.845	9.4929	16.08387356
	18 Bus Stops	0.853	1.812	3.570	0.185	1.512	2.453	1.412	11.025	17.949	1.567	9.2514	15.44431769
Based on Frequency	15 Bus Stops	0.962	1.810	3.678	0.340	2.056	3.424	0.471	2.712	4.539	1.839	6.9355	12.24240077
	16 Bus Stops	1.000	2.075	4.112	0.433	2.590	4.319	1.647	11.211	18.464	2.798	10.964	19.24452604
	17 Bus Stops	0.937	2.002	3.940	0.218	1.530	2.513	1.424	11.024	17.961	1.845	9.4929	16.08387356
	18 Bus Stops	0.903	1.975	3.866	0.184	1.512	2.452	1.412	11.025	17.949	1.567	9.2514	15.44431769

Table 11: Average Lateness

Ahead-of-Schedule Leaving Storage Time				
	5 Minutes	10 Minutes	15 Minutes	20 Minutes

Based on Destination	15 Bus Stops	5.462%	18.487%	30.252%	48.739%
	16 Bus Stops	5.042%	15.546%	26.471%	44.118%
	17 Bus Stops	3.361%	10.924%	23.109%	42.017%
	18 Bus Stops	2.521%	7.563%	19.328%	37.815%
Based on Frequency	15 Bus Stops	5.882%	15.546%	29.412%	49.160%
	16 Bus Stops	5.462%	15.021%	25.630%	43.697%
	17 Bus Stops	3.782%	10.084%	22.269%	41.597%
	18 Bus Stops	2.941%	7.143%	19.328%	37.815%

Table 12: Percentage of Delayed Loading Process

		<i>Ahead-of-Schedule Leaving Storage Time</i>			
		<i>5 Minutes</i>	<i>10 Minutes</i>	<i>15 Minutes</i>	<i>20 Minutes</i>
Based on Destination	15 Bus Stops	21.053%	33.962%	50.877%	59.649%
	16 Bus Stops	21.053%	35.088%	50.877%	59.649%
	17 Bus Stops	21.053%	33.333%	50.877%	59.649%
	18 Bus Stops	21.053%	35.088%	50.877%	59.649%
Based on Frequency	15 Bus Stops	7.018%	12.500%	24.561%	26.316%
	16 Bus Stops	7.018%	19.298%	24.561%	26.316%
	17 Bus Stops	7.018%	19.298%	24.561%	26.316%
	18 Bus Stops	7.018%	19.298%	24.561%	26.316%

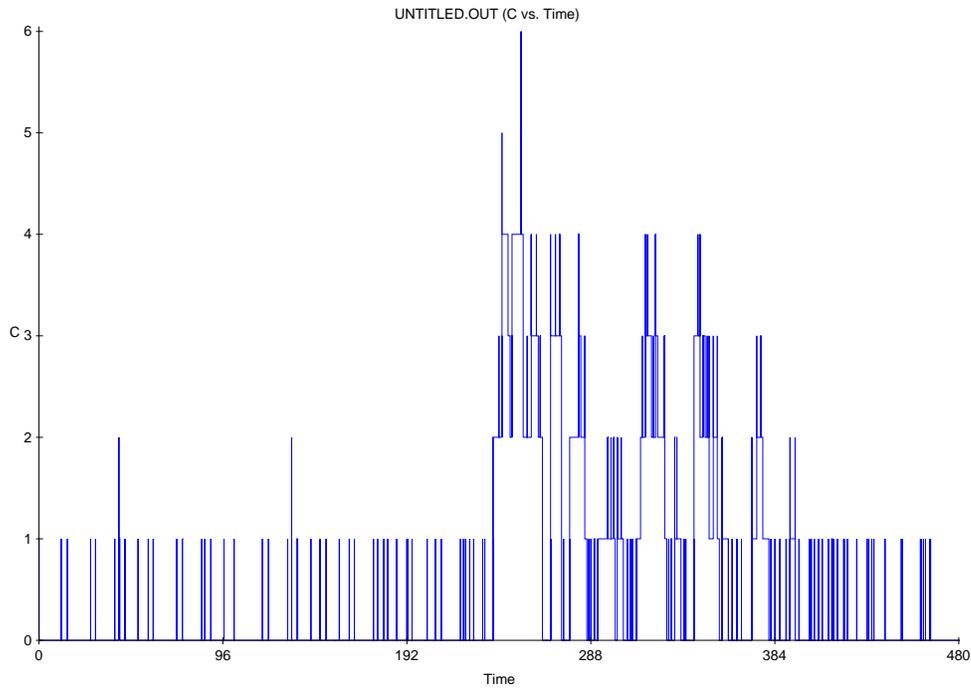
Table 13: Percentage of Delayed Unloading Process

		<i>Ahead-of-Schedule Leaving Storage Time</i>			
		<i>5 Minutes</i>	<i>10 Minutes</i>	<i>15 Minutes</i>	<i>20 Minutes</i>
Based on Destination	15 Bus Stops	32.773%	12.185%	11.765%	15.966%
	16 Bus Stops	32.773%	8.403%	7.983%	10.924%
	17 Bus Stops	32.353%	6.723%	5.882%	7.143%
	18 Bus Stops	31.513%	4.622%	4.622%	5.462%
Based on Frequency	15 Bus Stops	33.193%	8.824%	7.143%	11.765%
	16 Bus Stops	32.353%	8.403%	7.563%	10.924%
	17 Bus Stops	31.933%	6.723%	5.462%	7.143%
	18 Bus Stops	30.672%	4.202%	4.622%	5.462%

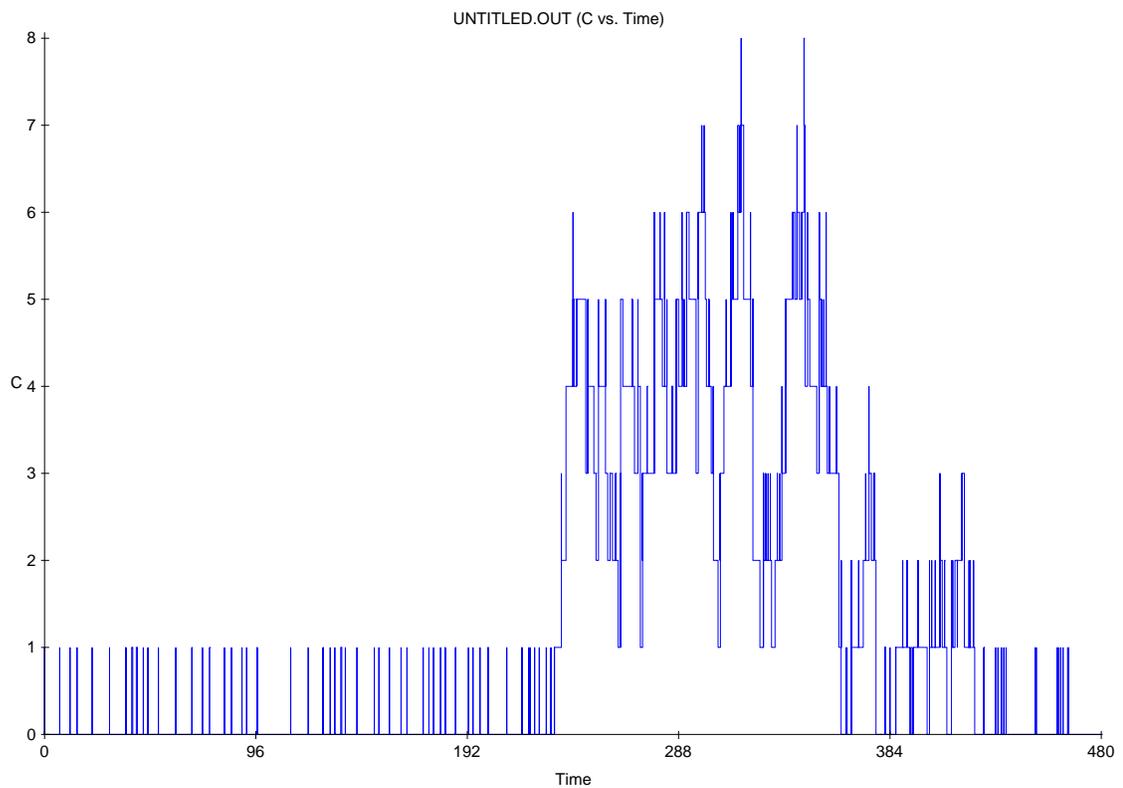
Table 14: Percentage of Being Late for Departure

5.2 Circulating Process inside the Terminal

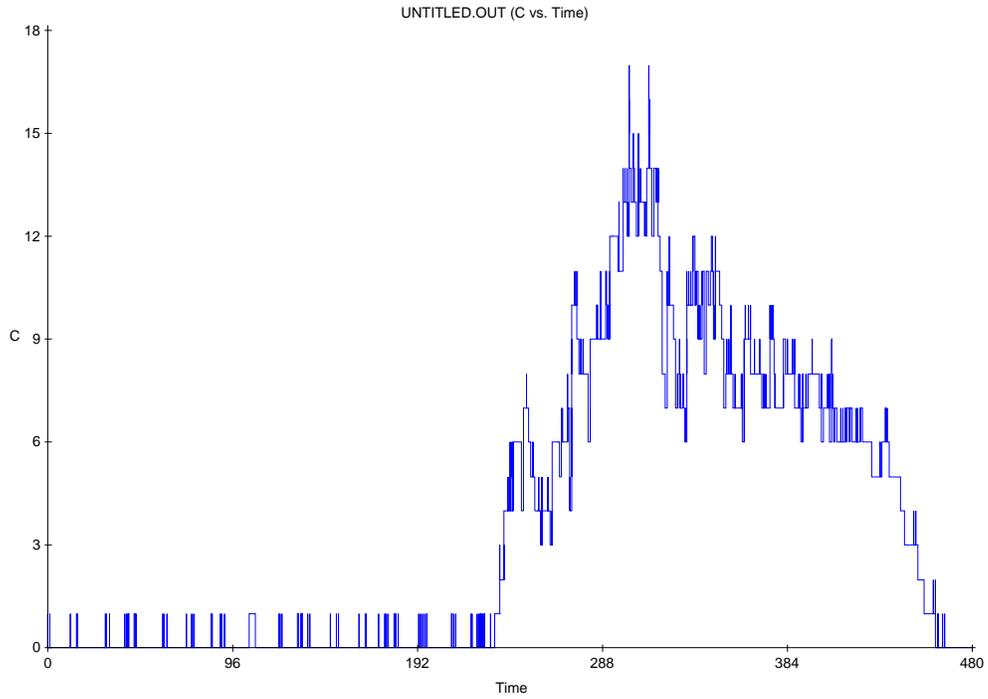
We set up our model such that it can display the number of buses circulating in the terminal at any time during our simulation period. From the plots generated by our simulation, we find out that the number of circulating buses has no relation with number of bus stops as well as bus stop layout, because graphs are exactly the same regardless those graphs with different number of bus stops and different layout method. Yet the graphs do change dramatically when we change the ahead-of-schedule leaving storage time. The plots associated with number of circulating buses are provided below.



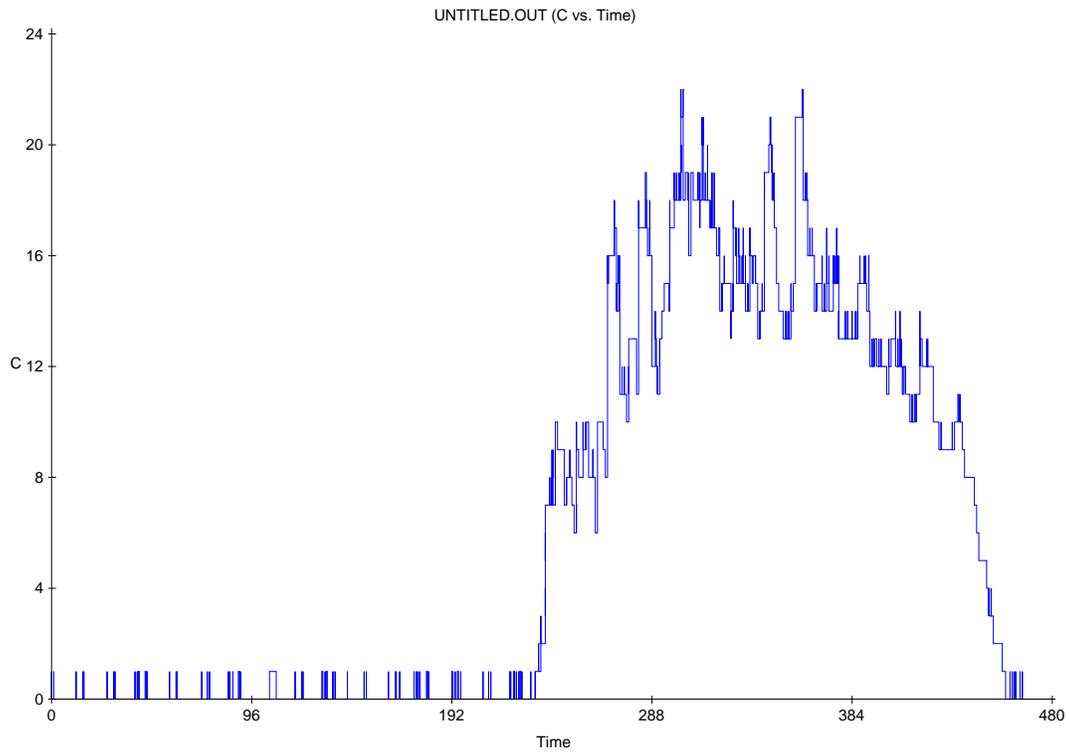
**Graph 1: Output Graph for Number of Circulating Buses
(5 minutes for Ahead-of-schedule Leaving Time)**



**Graph 2: Output Graph for Number of Circulating Buses
(10 minutes for Ahead-of-schedule Leaving Time)**



Graph 3: Output Graph for Number of Circulating Buses (15 minutes for Ahead-of-schedule Leaving Time)



Graph 4: Output Graph for Number of Circulating Buses (20 minutes for Ahead-of-schedule Leaving Time)

The highest number of buses in circulating occurs around 4-5pm, and this time period increases as the raise of ahead-of-schedule leaving storage time. The peak point also increases as the raise of ahead-of-schedule leaving storage time, and it is 6 when ahead-of-schedule leaving storage time is 5 minute, 8 when this time changes to 10 minutes, 17 when the time is 15 minutes, and finally 23 when the time is 20 minutes. Based on the fact that the Temporary terminal is 0.5 miles for a lap, 15 and 20-minute ahead-of-schedule leaving storage time would create traffic in the terminal, and hence these policies are infeasible.

5.3 Performance of the Storage

For the storage problem, rather than assign the storage with a fixed capacity, instead, we generate the cumulative quantity of buses in the reservoir during noon to 7pm through our sigma simulation. For each simulation run, we would change all the three input variables, bus stop layout (by destination or by frequency), number of bus stops (15, 16, 17 and 18), and ahead-of-schedule time (5min, 10min, 15min and 20min). Hence, there are total of 32 simulation runs. In each case, we know how many storage spaces are needed to operate the Terminal sufficiently.

Since our model only simulates from noon to 7 pm, we must determine the number of buses that has been in the storage by noon, and it is the initial number of buses in the storage in our model.

During our simulation run from noon to 7pm, three possible types of buses would go to the storage:

1. By noon, there are already some buses storing in the reservoir. All those buses are coming from the Eastbay before noon and stay in the terminal storage for peak-hour westbound call out. By inspecting the schedule our client provided us, we observe that there are 14 buses coming from the Eastbay to the terminal storage in the morning and all leaves between noon to 7 pm.
2. during noon to 7pm, if buses arrive much earlier than their schedule leaving time, it will stay in the storage until ahead-of-schedule leave storage time $t_{als}(\text{min})$ before their leaving time. In our optimal case when $t_{als} = 10$ minutes, for instance, a bus arrives terminal at 3pm with scheduled departure time of 4pm goes to storage after its unloading process. It comes out from storage at 3:50pm and begins its loading process.
3. The three cases are buses come from East Bay during a day and stay over night in the terminal storage. This is not possible in current situation because there is no technical support in the terminal storage. Therefore, all buses will park in the Oakland couch yard over night.

The first two cases of staging are included in our model. Number of the type 1 staging is the initial value for the STRG variable. By the end of our simulation, the bus stop taken by the type 1 staging should be equal to zero. This is because the initial staging in the terminal is 14 at

noon and there are 14 type 1 staging buses leaving the storage during noon to 7pm. Therefore, the storage spaces taken by type 1 buses should be zero by 7 pm.

According to the schedule, there are 238 buses arriving at the terminal during noon to 7pm in a day. These buses include 14 buses from the storage, 159 of empty buses from the Eastbay, and 65 buses with passengers from the Eastbay. Furthermore, we pick out all the buses that are indicated to enter or leave the terminal storage in the Schedule Report. We discover that few buses have the fixed schedule to enter or leave the terminal storage. In the morning, there are only arrival events in the storage and there are only departure events in the afternoon. Only the buses (100 line series) serve in the terminal would have fixed schedule to enter the terminal. The number of arrival in the morning is the same as the number of departure; this suggests that no buses would park in the storage over night. In conclusion, the initial value of storage we should input in the model is just the number sum of total entering in the terminal given by Schedule Report, and this number is 14. We attached information of all the buses go into and leave the terminal in the appendix.

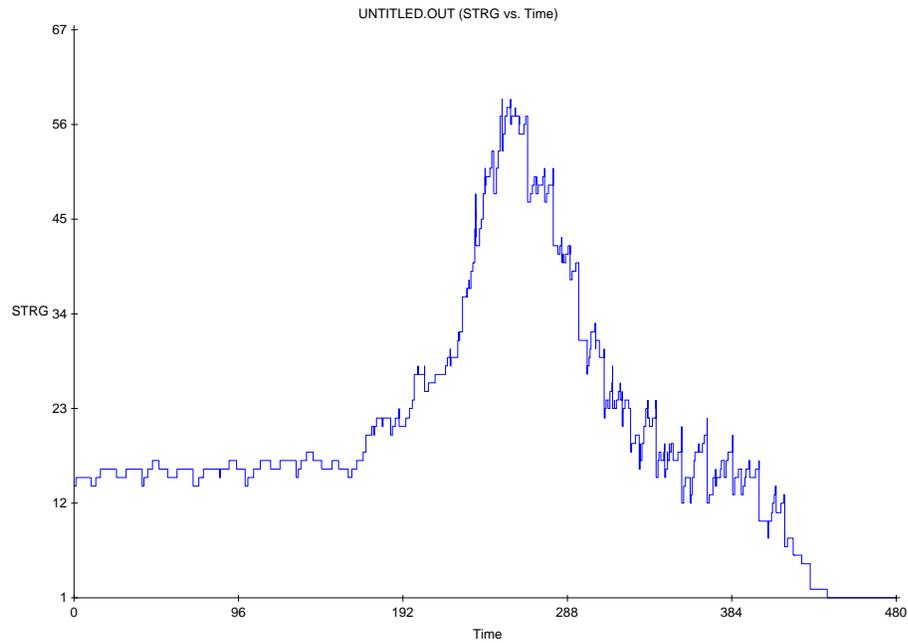
Our model can trace out number of buses in the storage at any specific time. However, since the goal of our project is to find out how much storage spaces are needed in the terminal, we just have to find out the maximize number of buses stored in storage in a day. In addition, the peak number should appear in the afternoon, because right before rush hour begins, many empty buses from the East Bay will arrive at the terminal much earlier than its schedule departure time. Hence, number of staging buses will built up during that period. Furthermore, the initial staging buses at noon will increase as the eastbound buses in the afternoon increase. The maximum historical number is 25. In order to meet the future demand, we decide that besides the current 14 buses we can find in the schedule, we would add 11 more storage spaces upon the maximum number of storage spaces, which allow the storage to satisfy the maximum historical number. Therefore, the total storage spaces that the terminal needs should be the peak number of staging buses plus 11.

The table below is the maximum number of storage spaces needed with different input variables according to current schedule.

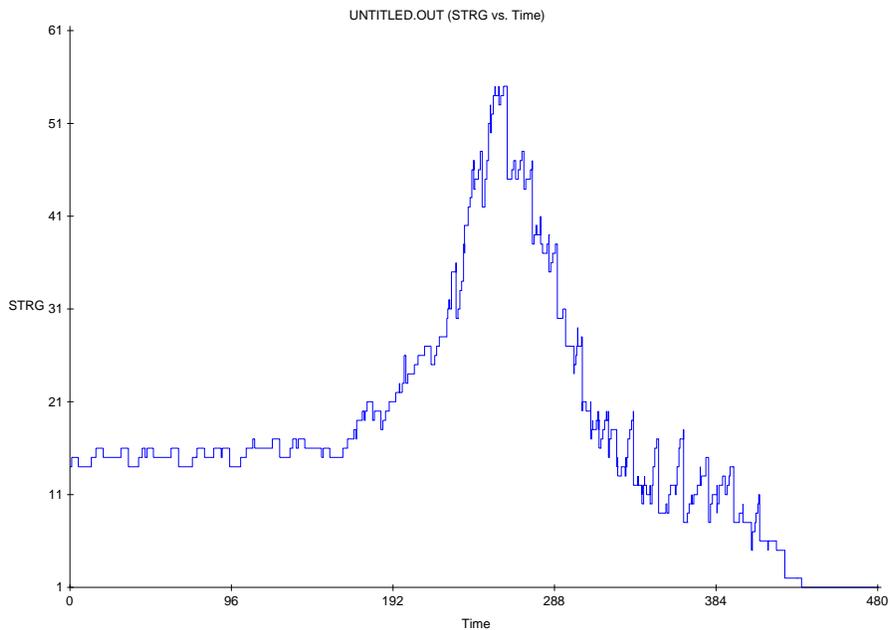
	<i>5 minutes</i>	<i>10 minutes</i>	<i>15 minutes</i>	<i>20 minutes</i>
<i>Based on Destination</i>				
15 Bus Stops	59	55	53	47
16 Bus Stops	59	55	53	47
17 Bus Stops	59	55	53	47
18 Bus Stops	59	55	53	47
Total Number of Bus Stops	59	55	53	47
<i>Based on Frequency</i>				
15 Bus Stops	59	55	53	47
16 Bus Stops	59	55	53	47
17 Bus Stops	59	55	53	47
18 Bus Stops	59	55	53	47
Total Number of Bus Stops	59	55	53	47

Table 15: Maximum Number of Storages

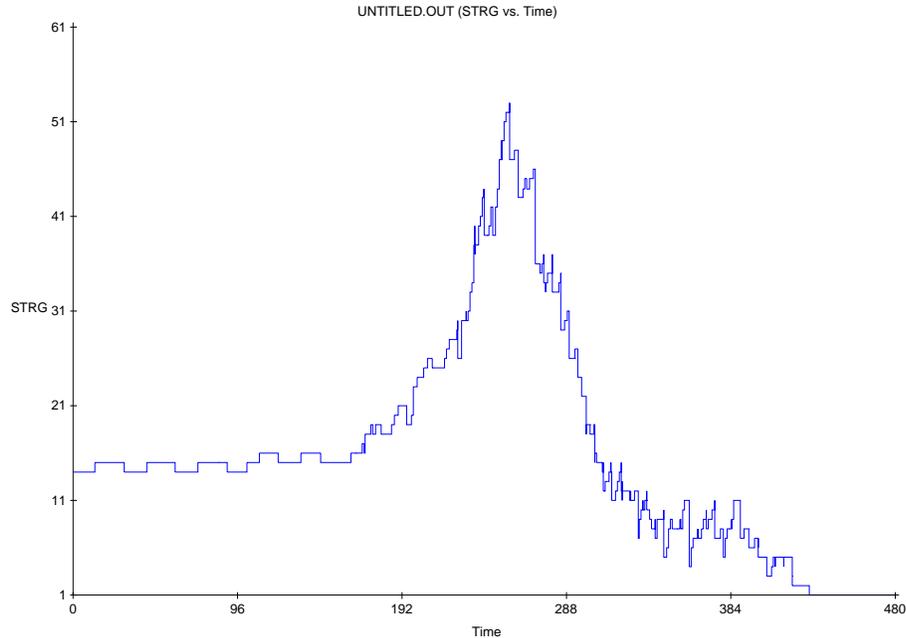
Here are the simulation output graphs to the number of bus in storage by inputting different Ahead-of-schedule leaving time.



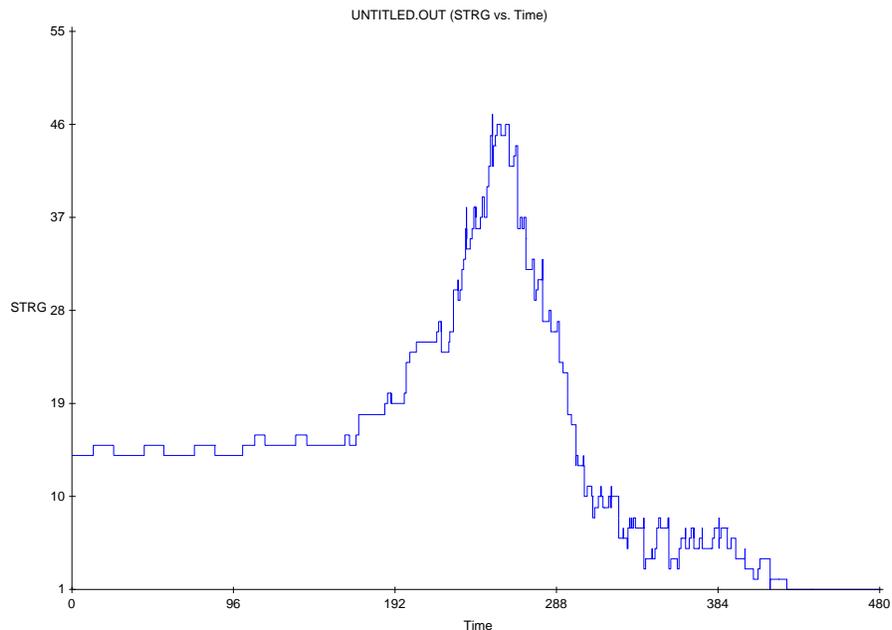
**Graph 5: Output Graph for Number of Bus in Storage
(5 minutes for Ahead-of-schedule Leaving Time)**



**Graph 6: Output Graph for Number of Bus in Storage
(10 minutes for Ahead-of-schedule Leaving Time)**



**Graph 7: Output Graph for Number of Bus in Storage
(15 minutes for Ahead-of-schedule Leaving Time)**



**Graph 8: Output Graph for Number of Bus in Storage
(20 minutes for Ahead-of-schedule Leaving Time)**

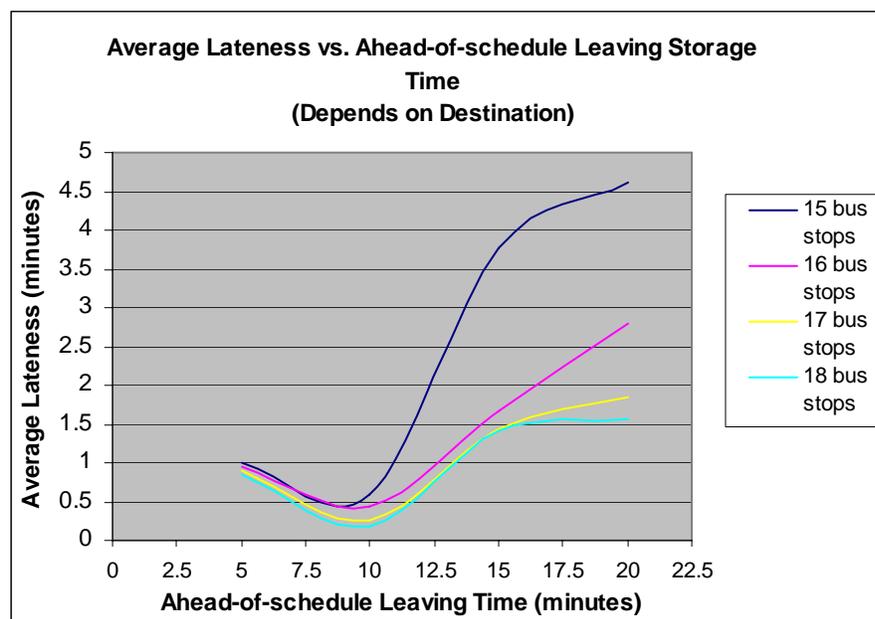
By looking at the graphs, we find out that changing the total number of bus stops in the terminal and the layout method do not affect the peak number of buses in the storage. All of them have the same pattern over time. The overall peak hours is around 3:20pm (200 minutes in the model) to 4:48pm (288 minutes in the model). Therefore, we try to find out a way to reduce the number of incoming buses to the storage. Accordingly, we change the time period for Ahead-

of-schedule Leaving Storage to 5 minutes, 10 minutes, 15 minutes, and 20 minutes respectively to adjust the time that the bus stays in the storage and the number of incoming buses to the storage. The reason is that the longer time that a bus stays in storage requires more spaces in the storage. And moreover, if t_{asl} is longer, more buses will go to loading directly without entering the storage. Even though shorter Ahead-of-schedule Leaving Storage time decreases the required storage spaces, it will definitely worsen the on-time performance of the bus loading process.

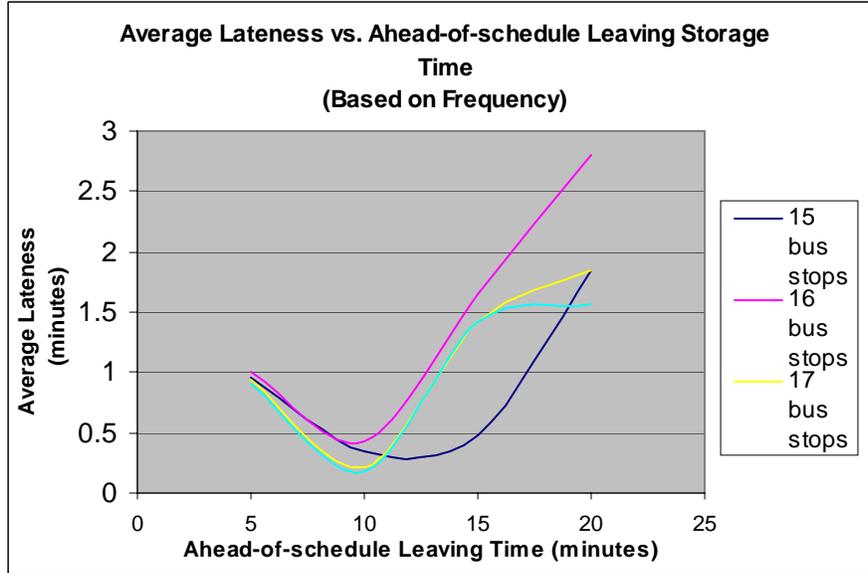
Graph 9 and Graph 10 are the plots of the average lateness versus Ahead-of-schedule Leaving Storage Time. Based on these two graphs, we observe that approximate 9-minute ahead of scheduled loading process can result in the minimum average lateness. In addition, by examining Graph 11 and Graph 12, that is, the percentage of lateness vs. Ahead-of-schedule Leaving Storage Time, 9-minute can also result in the lowest percentage of lateness.

The average lateness has increased as the raise of Ahead-of-schedule Leaving Storage Time. This result is not surprising. The earlier buses leave from the storage, the longer duration they need to stay inside the terminal by parking at the bus stop or circulating the terminal since they have nowhere else to go. However, the Ahead-of-schedule Leaving Storage Time cannot be too short. For instance, 5-minute causes the highest percentage of being late for departure. The reason is that it usually takes 2 minutes for a bus to arrive a bus stop, and therefore a bus usually cannot finish loading process in the rest 3 minutes. Thus, it might cause lateness.

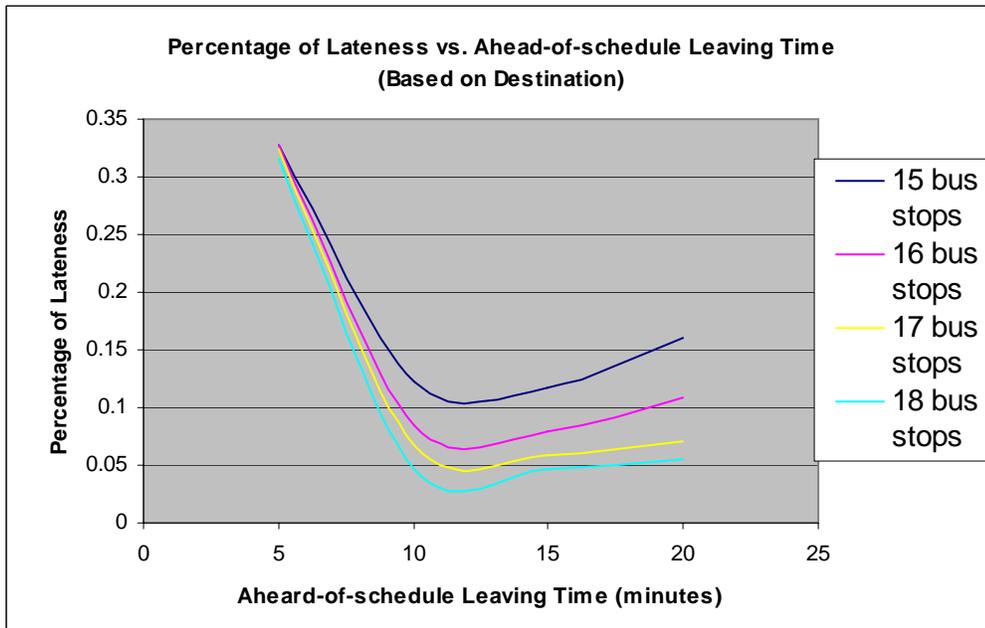
Hence, from above analysis, we recommend that AC Transit should assign the buses to leave the storage 9 minutes earlier than the scheduled time for the departure in order to achieve the best on-time performance.



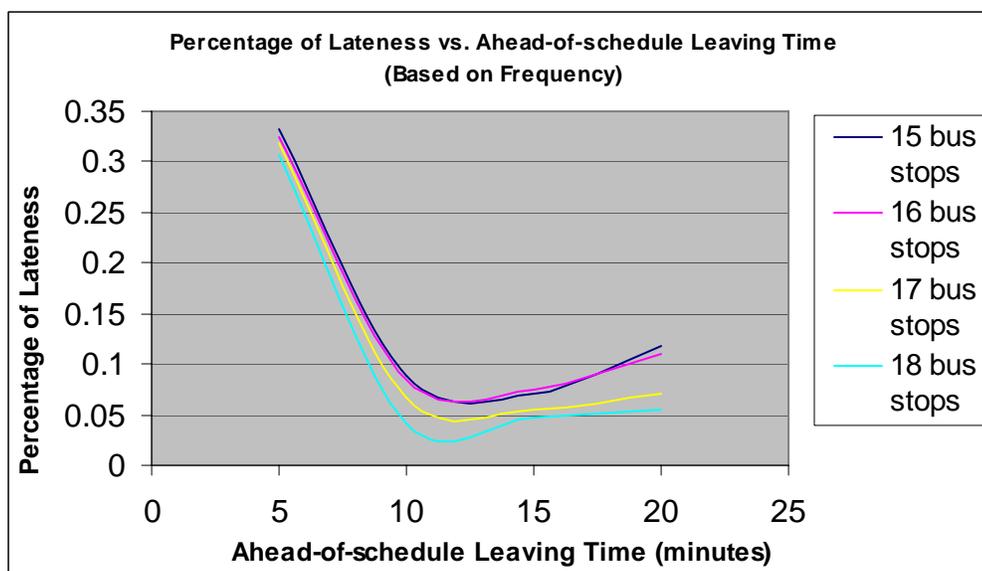
Graph 9: Average Lateness vs. Ahead-of-schedule Leaving Storage Time (Based on Destination)



Graph 10: Average Lateness vs. Ahead-of-schedule Leaving Storage Time (Based on Frequency)



Graph 11: Percentage of Lateness vs. Ahead-of-schedule Leaving Time (Based on Destination)



Graph 12: Percentage of Lateness vs. Ahead-of-schedule Leaving Time (Base on Frequency)

5.4 Quick Payment Method – Special Pass

We also analyze the simulation by changing the whole payment method to special pass (i.e. class pass using in Berkeley) only. Since in the pervious sensitivity analysis, the “10-minute Ahead-of-schedule Leaving Storage Time” is the most efficiency setting in our model, we therefore use this setting again, 16 bus stops layout, and plus this special pass payment method to run the simulation again. The results are listed in Table 16.

16 bus stops (10 minutes)	Based on Destination		Based on Frequency	
	Special Pass	Current payment method	Special Pass	Current payment method
Average Waiting Time to Load (mintues)	0.908	1.021	0.882	1.017
Average Waiting Time to Unload (minutes)	0.109	0.109	0.060	0.060
Average Lateness (minutes)	0.189	0.433	0.189	0.433
Percentage of Delayed Loading Process	13.45%	15.55%	12.61%	15.02%
Percentage of Delayed Unloading Process	35.09%	35.09%	19.30%	19.30%
Percentage of Being Late for Departurn	1.68%	8.40%	1.68%	8.40%

Table 16: Operation Performance Using Special Pass

Compared to the pervious result, the on-time performance on departure process is much better by using the special pass method. The average lateness is only 0.189 minutes, and the percentage of being late for departure is 1.7%. Since the demand for AC Transit Transbay Service will be higher in the future, this advantage of quick payment method will be more

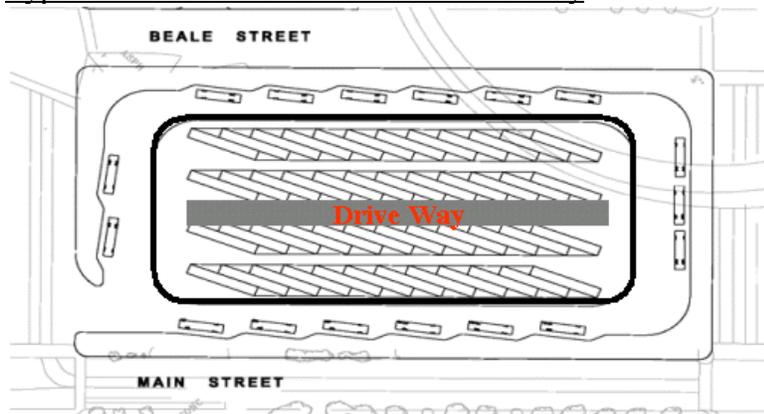
obvious. Hence, we believe Special-Pass-Only payment method will sufficiently support the future demand.

5.5 Storage Design

Here are several brainstorms for the layout inside the storage.

Both Type 1 and Type 2 have an internal drive way, and all buses are parked inclined with a 30 or 45 degree.

Type 1: Bounded with an Internal Drive Way



Graph 13: Storage layout bounded with an Interval Drive Way

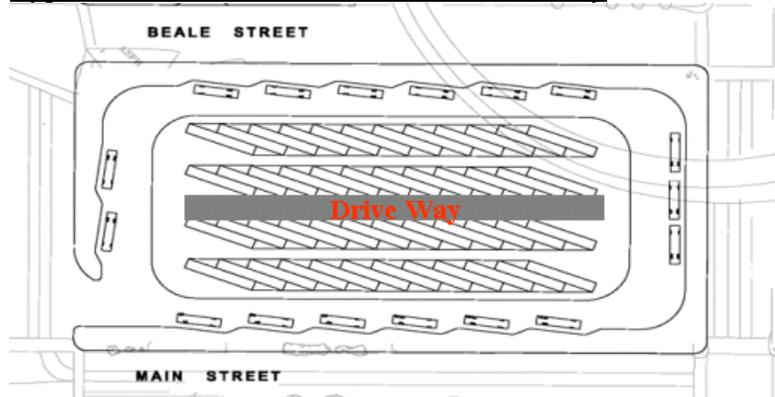
Advantage:

- Higher flexibility – at least two rows of buses closed to the internal drive way and can easily get in/out of the storage place.
- Safety issue – lower bus crash risk

Disadvantage:

- Compared to type 3 and 4, wastage of storage space

Type 2: Boundless with an Internal Drive Way



Graph 14: Storage layout boundless with an Internal Drive Way

Advantage:

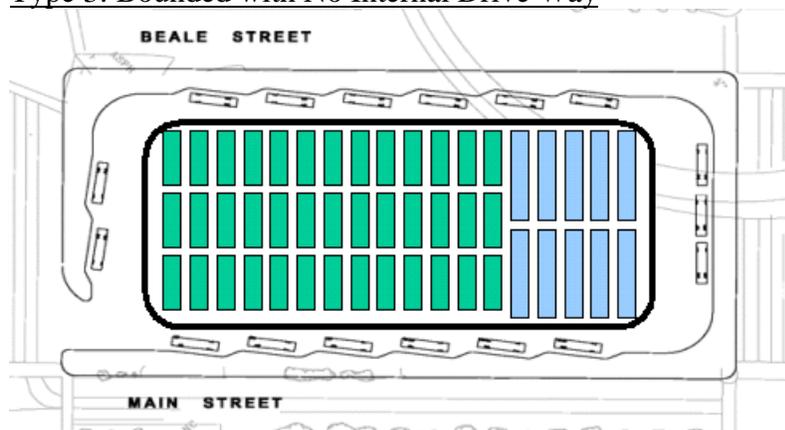
- The highest flexibility – all the four rows of buses can easily get in/out of the storage place.

Disadvantage:

- Compared to type 3 and 4, wastage of storage space
- Safety issue – higher risk for bus crash and passenger injury.

Both Type 3 and Type 4 do not have an internal driveway, and all buses are parked straightly.

Type 3: Bounded with No Internal Drive Way



Graph 15: Storage layout bounded with No Internal Drive Way

Advantage:

- Save lots of storage spaces

Disadvantage:

- The lowest flexibility – only the several buses closed to the exit can easily get in/out of the storage place
- Safety issue – lower bus crash risk.

Type 4: Boundless with No Internal Drive Way



Graph 16: Storage layout boundless with No Internal Drive Way

Advantage:

- Higher flexibility – buses closed to drive ways can easily get in/out of the storage place.
- Save lots of storage spaces

Disadvantage:

- Safety issue – higher risk for bus crash and passenger injury.
- Compared to type 2, lower flexibility

6.0 Summary and Recommendation

6.1 Simulation Model Summary

After analyzing in depth of the current and future AC Transit Transbay Terminal's situation, we develop a model that can simulate activities inside the Temporary Transbay Terminal. Our model is able to show every bus's flow process in the terminal. Furthermore, it can keep track of number of buses in the storage, number of buses circulating in the terminal as well as the queue for unloading and loading process for each bus stop at any time during the simulation period. This model does not merely build for the current data, and it is flexible enough so that AC Transit can still use it to accurately simulate with different schedules in the future. Due to the difficulty to predict the traffic condition, we only consider on-time arrival buses currently. However, the model also works for non on-time arrival as long as users provide information regarding the variance of buses' arrival time.

6.2 Recommendations on Terminal Operation

6.2.1 Passenger Platform Design

According to one of our observations that most people tend to arrange the waiting line through the aid of physical object such as fence can continue to build the fence along the passenger platform to ensure safety issue as well as passengers' psychological phenomenon.

Terminal can also choose shapes of the platform between straight-line and saw-tooth platform. There are some pros and cons for straight-line design. It fits all the three different sizes of buses, but this straight-line design might not be safe enough to load passengers, especially for seniors and children. The major benefit of the saw-tooth design is the safety issue to the passengers, and the minor disadvantage is complication of the design and waste of space

6.2.2 Operation in Storage

At present, after the unloading process, some of the buses that do not have loading process schedule will still remain in the storage. In fact, this kind of buses can leave the terminal right after the unloading process and park on the street. That will not occupy the storage spaces and it will smooth the terminal operation.

6.2.3 The usage of Sensor Light

During peak hours, it might be helpful to have a system to indicate frequently arrival buses for available spot in temporary Transbay terminal.

In addition, the usage of sensor light is based on first-come-first-serve policy. In running the simulation model, we find out that huge average loading time causes some buses missing in the "Finish Loading" process. The reason is that there are too many buses occupying the bus stops, and some buses cannot find a spot to load passengers. For example, while some "unfortunate" buses are circulating the bus stops, some of their successors have already found a spot to load passengers. Since the loading process take a lot of time, these "unfortunate" buses have to circulate again and again. Therefore, the first-come-first-serve policy is needed.

6.2.4 "Quick-Payment Method"

The current payment methods compose of bus pass, cash payment and special pass. From the previous analysis, we can see that cash payment and bus pass take relative longer time due to the validation time of the ticket machine on buses. It, therefore, increases the overall loading time and lowers the on-time performance for the buses. As we know, AC Transit Temporary Terminal has been reduced to a much smaller size. A delayed departure for one bus might affect its successors' on-time performance. To avoid this situation, it is necessary to keep the buses departure on time as much as possible. One way to do this is to make sure the bus can completely finishes its loading process before its schedule leaving time—this requires to minimize the total loading time for bus. Improving the current payment methods can decrease bus' average loading time. We recommend a few payment methods to substitute the current ones.

1. Advance payment method—using the idea of BART: all passengers must show payment proof to enter the terminal, and they can get on the bus ticketless. This method can

completely save the time for riders to insert the bus pass or cash into the machine in the bus. However, the shortcomings for this method are the cost for the new machines, the space to place these machines and the possibility of shifting the queue from the bus to the ticket machine.

2. Special pass payment method—changing the current bus pass to special pass (i.e. class pass in UC Berkeley). The percentage of cash payment is relative low. Even though it requires long loading time for passengers pay with cash, it does not contribute to the long overall loading time, and therefore we can still keep this minor payment method. More than 80% of the passengers are using bus pass. If we change the current bus pass to special pass, then it can save 1.4 seconds for each passenger. Section 6.4 proves the efficient of using special pass.
3. IC payment method— AC Transit can consider IC card payment method. That is, passengers can add money into their IC card whenever they want. When they enter the bus and insert the card into the machine, a standard amount of money will be deducted from the IC card. This is good for long-term AC Transit passengers. This disadvantage for this new payment method is the high cost to change the ticket equipments in each bus.

7.0 Conclusion

The purpose of this project was to solve the capacity issues arise due to the reduction of total available bus spaces in AC Transit's Temporary Transbay Terminal comparing to the existing one. Our model and detailed data analysis suggested an optimal layout and flow control system for AC Transit Transbay Terminal.

The first area of concern lay in the bus stop placement and bus loading process. Through Transbay Service bus schedules, we found out the minimum required number of bus stops was 15, because 14 stops will produce time conflict within current schedule. The maximum possible number of bus stops was 18 according to the dimension of future Temporary Terminal. After deciding which bus lines to share the same bus stop, we used two different layout methods to come up with the bus stop placements. Furthermore, we believed that adjusting the ahead-of-leaving-storage time directly affects buses' actual departure time.

Since our main goal for this project was to support AC Transit's normal Transbay Service during the Temporary Transbay Terminal period, the 10-minute ahead-of-leaving-storage time yields the best on-time departure performance. Therefore we recommended AC Transit to adopt this policy. The other area we needed to take care of was to determine the storage capacity. We found out the required storage spaces for 5, 10, 15, 20-minute ahead-of-leaving-storage time from our model. Finally, we also suggest that our analysis proved considering alternating current activities payment method to a more advance one can significantly improve buses' on-time performance in terminal.

8.0 Suggested Further Improvement for the Project

We recommend AC Transit to find a transportation engineer to simulate the traffic of the bus lanes inside the Terminal. Even though our model can compute how many buses circulating in the terminal at any time, we cannot build up actual traffic flow in the lanes due to the lack of

knowledge and tool on transportation simulation. However, this simulation is essential to ensure the safety of buses.

Due to the time constraint, we did not construct a user-friendly interface for our simulation model. Sigma is a powerful yet not common program, since not many people are familiar with it. A user-friendly interface will be helpful for people to understand the model easier, to input data, and to view output and graphs. However, we decide to put our effort on conducting deeper analysis on AC Transit's original concerns on the temporary terminal.

Design of passenger platform is an objective that we planned to do but could not finish. If there is more time, we need to confirm that the size of the passenger platform is adequate to ensure that the passenger loads may be accommodated safely. Minimum platform space required by each person as defined by the design criteria, which can be found from the TCRP Report's page 7-23. We use that number times the number of forecast future ridership to get the dimension of the passenger platform.

9.0References

1. Sigma Software: www.customsimulations.com
2. AC Transit Official Website: www.actransit.org
3. Transbay Terminal Project: <http://transbayproject.org>