MARKET STREET STUDY TECHNICAL REPORT

TRANSIT PERFORMANCE

This technical report is one of over a dozen reports prepared to support the Market Street Study. The purpose of the technical reports was to identify key issues and evaluate potential solutions. The techincal reports were developed in consultation with the Market Street Study Technical Working Group, which consisted of representatives from the San Francisco Department of Parking and Traffic, Municipal Railway, Planning Department, and Redevelopment Agency.

Supplemental assessments may be required prior to the implementation of some specific recommendations contain in the Market Street Study Action Plan.

Market Street Study

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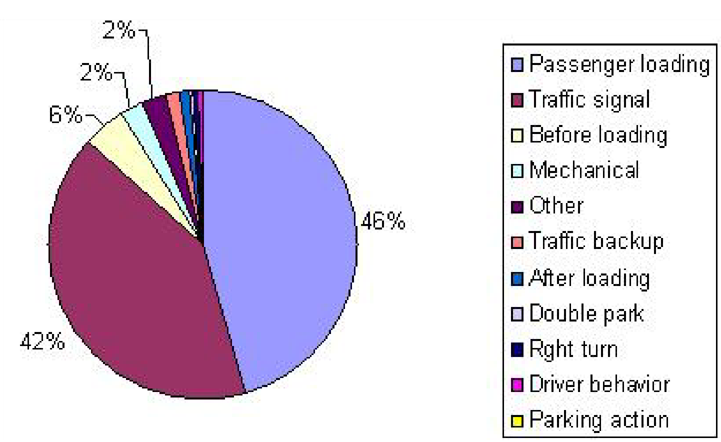
Transit Performance Technical Report

Background

Market Street is the spine of San Francisco's transit network. Approximately 20% of all MUNI routes and 25% of total MUNI ridership occurs along Market Street. During peak periods, over 7,000 passengers use Market Street transit each hour. At Market and Fifth Streets, one of the busiest multi-modal intersections in San Francisco, 160 buses per hour travel through the intersection during peak periods.

One of the goals of the Market Street Study is to decrease transit travel times and improve transit reliability. Based on in-vehicle surveys, there are a number of factors that contribute to transit delay along Market Street. As shown in Figure 1, the largest sources of transit delay are related to passenger loading and unloading (46%) and to delays at red lights (42%). Together, these two sources account for almost 90% of MUNI's travel delays along Market Street.

Figure 1. Sources of Transit Delay on Market Street



Source: SFCTA, 2002

Various remedies have been identified as means to decrease MUNI's travel times and improve transit reliability along Market Street. Two measures – providing improved transit-only lane enforcement and decreasing transit vehicle dwell times at transit stops – should be undertaken in the near future.

Four other potential solutions have been identified for analysis. Each of these four measures, described in the next section, would require fundamental changes in Market Street operations and could impact other modes. These measures, if successful, could be implemented individually or grouped as packages. In other words, the strategies can be considered as transit "building blocks."

The "Building Blocks"

Four fundamental "building blocks" for improving long-term transit performance along Market Street were studied:

1) Extending the transit-only lanes,
2) Extending the size of the center boarding islands,
3) Increasing green light duration along Market Street, and
4) Reducing the amount of automobile traffic and congestion on Market Street.

Using a computerized transit simulation model for Market Street, further described in the next section, assessments were made of each individual measure and combinations of the measures. The assessments also considered recommended short-term improvements such as reducing transit dwell time.

Center Lane Simulation Model

A computer-based delay and queuing simulation model was developed by the Authority to assist with determining to what extent each of the four fundamental "building block" measures could impact travel times and potentially extend queuing adjacent to the boarding islands. The simulation model was calibrated to estimate the average wait time for buses and cars and the average number and type of vehicles queuing in the center lane adjacent to the study boarding islands (intersections). The model allows testing of a variety of scenarios and is sensitive to several inputs, as shown in Table 1.

Table 1: Simulation Model Inputs and Outputs

Inputs	Outputs
Bus arrival rate: bus/second	Average bus waiting time: seconds
Automobile arrival rate: auto/second	Average automobile waiting time: seconds
Average vehicle dwell time: seconds/vehicle	Average no. of buses in queue: buses
Standard deviation of dwell time: seconds/vehicle	Average no. of automobiles in queue: autos
Green light duration: seconds	
Traffic signal progression: bus bunching factor	
Boarding island capacity: maximum no. of buses	

Results from the simulation model are reported in later sections of this memorandum.

Existing Boarding Island Demand and Capacity

As the first step in determining key boarding island passenger demands and capacities, MUNI's bus activity data was collected and analyzed, and overall traffic volumes and the street configuration for the portion of Market Street between Gough Street and Steuart Street were reviewed. Bus rotations (i.e., actual driver schedules) were used to determine the number of vehicles stopping at both the curb and center lane Market Street stops during the following time periods:

- AM peak hour (8:00-9:00 a.m.) and peak 15 minutes;
- Midday peak hour (2:00-3:00 p.m.) and peak 15 minutes and
- PM peak hour (5:00-6:00 p.m.) and peak 15 minutes.

Attachment A shows the number of MUNI vehicles arriving at each of the curb and center lane stops during each time period. Table 2 shows which MUNI lines stop at either the curb or center lane pads. The location of these stops can be seen in Attachment B, which illustrates MUNI's Market Street operations in detail.

Table 2: Summary of MUNI Stop Locations by Line

Inbound		Outbound	
Curb	**Center**	**Curb**	**Center**
5	2	2	6
6	7	5	7
16A	9	16A	9
16B	21	16B	26
38	26	21	66
38L	31	31	71
	66	38	71L
	71	38L	F
	71L		
	F		

Based on the above information and on feedback from the Authority and the Technical Working Group, the following inbound intersection locations were selected for boarding island analysis: Seventh, Fourth, Third, Second, and First Streets. The following outbound intersections were chosen: Front, Montgomery, Kearny, Stockton, and Powell Streets. In addition, the current usage of four bus stop pairs (one island, one curbside) was evaluated at the following locations: 4th & Market (inbound), 1st & Market (inbound), Powell & Market (outbound), and Sansome/Montgomery & Market (outbound). These bus stop pairs were selected for analysis due to their current high usage.

The inbound pairs were observed during the a.m. peak hour (8-9 a.m.), and the outbound pairs were investigated during the p.m. peak hour (5-6 p.m.). According to MUNI bus graph data, these locations have the greatest number of curb and center island boardings and alightings combined, and were selected for this reason.

The standing population (i.e., waiting patrons) at each bus stop was counted during the one-hour peak period. At the arrival of each bus, the surveyor recorded the bus route number, the standing population at arrival, the number of boarding patrons, and the number of alighting patrons.

MUNI does not have a standard for the platform area required per patron on street islands. Consequently, the Transit Cooperative Research Program's 1999 *Transit Capacity and Quality of Service Manual* was referenced. While the manual did not recommend a standard to be used for evaluating bus stop or boarding island capacity, it did confirm that using passenger space requirements is an accepted method for measuring transit passenger capacity.

To develop a numeric standard, BART's current standard of five square feet of platform space per passenger was modified by adding an additional "diversity factor" of two square feet (providing a total of seven square feet per passenger). This "diversity factor", taken from the *Transit Capacity and Quality of Service Manual,* accounts for the non-uniform passenger distribution on MUNI's boarding islands, since passengers typically bunch up near the portion of the island adjacent to the crosswalk and around entrance and exit doors and must move to different positions on the platform when their bus arrives.

The available platform area is equal to the gross platform area minus a platform edge clearance of two feet. The edge clearance is preserved for safety, and also for circulation when buses are loading and unloading. A platform edge clearance was used only on the boarding side of the island, as there is a safety rail installed on the opposite side of the island that allows for full use of the space up to the actual railing-side edge of the island.

Using the seven square feet per person standard, Table 3 presents a conservative scenario showing the maximum number of patrons that can be accommodated at each of the four island platforms investigated.

Table 3: MUNI Platform Patron Capacity

Location	Length	Width	Platform Area (with Clearance Zone)	Person Capacity @ 7 s.f. Per Person
4th Street, Inbound	105'	4'-8"	289 s.f.	41
1st Street, Inbound	92'	6'	368 s.f.	52
Powell, Outbound	101'	5'	303 s.f.	43
Sansome/Mont., Outbound	100'	5'	300 s.f.	43

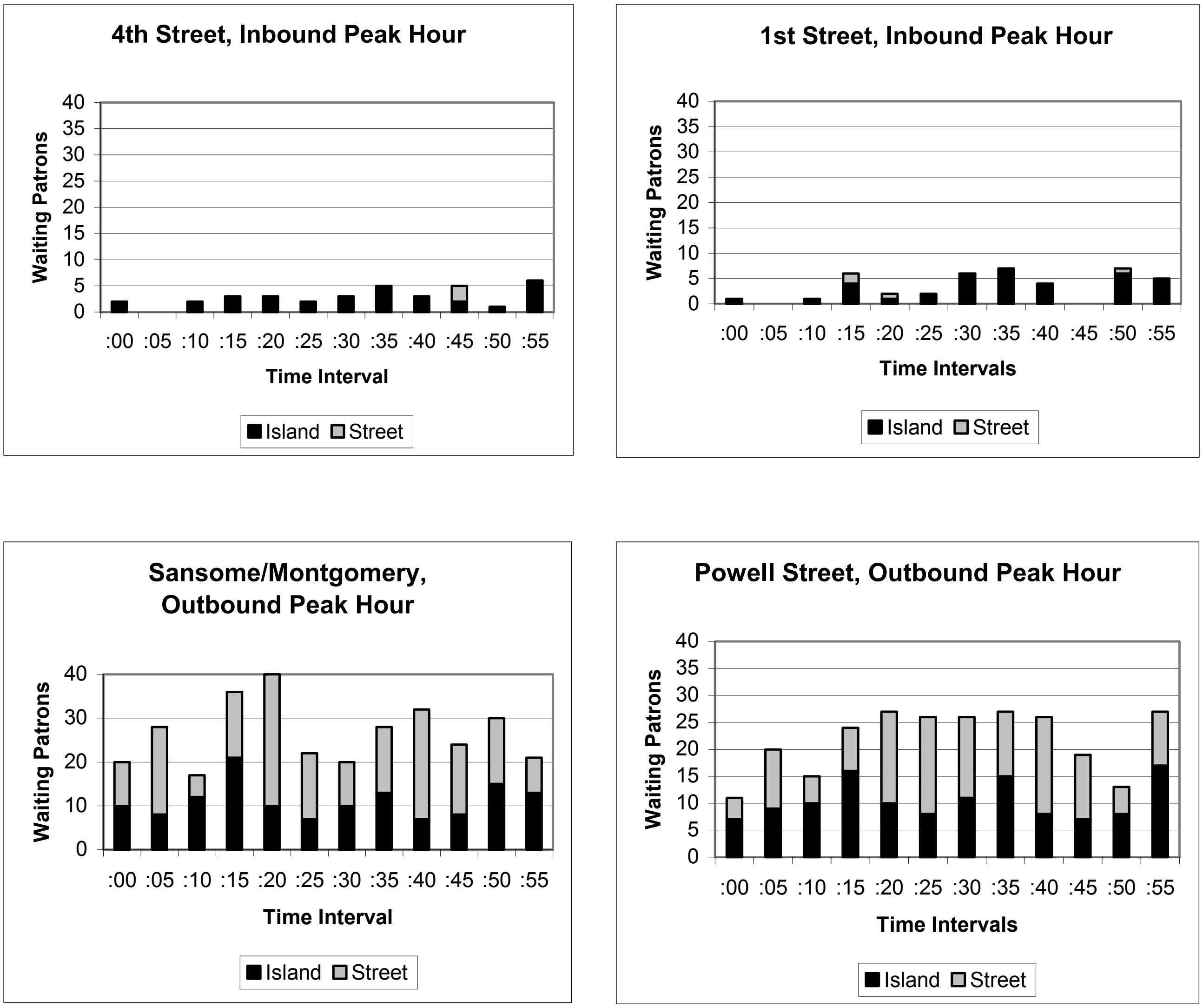
In general, the capacities of the bus islands were in excess of the number of passengers waiting to board buses. The most congested conditions occurred in the outbound direction during the evening peak, as would be expected. Even during this period, however, the number of people waiting on the center platforms varied from four to 30 people, depending on the frequency of bus arrivals. Table 4 shows the range of observed populations at each stop.

Table 4: Populations at Selected Market Street Bus Stops

Location	Observation Time	Waiting Population, Island	Waiting Population, Street
4th Street Inbound	8-9 a.m.	0-7	0-2
1st Street Inbound	8-9 a.m.	0-6	0-3
Powell Outbound	5-6 p.m.	3-21	4-30
Sansome/Mont. Outbound	5-6 p.m.	2-27	3-18

Figure 2 shows the variation in passenger loads throughout the peak hour at the bus stops surveyed. Activity throughout the hour varied significantly, although counts at or near the maximum were observed at multiple intervals.

Figure 2. Sample of MUNI Passenger Loads During Peak Hour



Source: Nelson\Nygaard, 2003

Center Lane Simulation Model Results

Sixteen scenarios, including existing conditions, were evaluated with the simulation model. These scenarios incorporated the transit building blocks in various combinations. Table 5 describes the inputs to each of the scenarios. Attachment C summarizes each scenario's impact on center lane travel times and queuing at adjacent boarding islands.

The various scenarios considered the following parameters:

- 2 or 4 lane transit operation: Under the 4-lane scenario, buses and streetcars would continue to operate in their current center or curbside travel lanes. In the 2-lane scenario, all buses and streetcars would operate in the center lanes, except when transitioning to and from Market Street.

- 2 or 3 transit vehicle boarding island capacity: It was assumed that most boarding islands can currently accommodate two transit vehicles. Some scenarios assumed that the boarding islands would be extended or lengthened to service three transit vehicles concurrently.

- Traffic signal timing changes: Market Street's existing traffic signal timing was assumed for most scenarios. To test the effect of increasing the duration of green time along Market Street, some scenarios considered additional green time at key intersections (up to 50% of the signal cycle).

- Automobile traffic volumes in the center lanes: Various levels of existing automobile traffic volumes were assumed in the center lanes, from 100% to 5% of existing traffic. Automobile volumes would be reduced by a variety of means, including provision of extended transit-only lanes, signage and vehicle turn restrictions.

- Changes to transit vehicle dwell times: To account for the potential of increased transit vehicle dwell times due to periodic center lane congestion, several scenarios assumed that MUNI vehicles would be exposed to greater dwell times than are currently experienced. This was accounted for by increasing dwell times by 10%, as well as their standard deviation by 25%. These variations were based on survey data, observations, and discussions with MUNI.

- Effect of transit vehicle "bunching": The computerized simulation model considers the effects of transit vehicle platooning and traffic signal progression. The modeled traffic streams typically result in two or more buses bunched together at and between transit stops, similar to existing operations.

Table 5: Summary of Transit Scenarios Evaluated with Simulation Model

Parameter	Existing	Scenario 1	Scenario 2	Scenario 3A
2 or 4 Lane Operation	4	2	2	4
2 or 3 Bus Boarding Island	2	2	2	2
Signal Timing	Existing	Existing	Existing	Existing
Center Lane Auto Volumes	Existing	50% of Existing	5% of Existing	80% of Existing
Transit Vehicle Dwell Time	Existing	Existing + 10%	Existing + 10%	Existing
Dwell Time Std. Deviation	Existing	Existing + 25%	Existing + 25%	Existing
Bus Bunching/Progression	Yes	Yes	Yes	Yes

Parameter	Scenario 3B	Scenario 3C	Scenario 4	Scenario 5
2 or 4 Lane Operation	4	4	4	2
2 or 3 Bus Boarding Island	2	2	3	3
Signal Timing	Existing	Existing	Existing	Existing
Center Lane Auto Volumes	60% of Existing	40% of Existing	Existing	50% of Existing
Transit Vehicle Dwell Time	Existing	Existing	Existing + 10%	Existing + 10%
Dwell Time Std. Deviation	Existing	Existing	Existing + 25%	Existing + 25%
Bus Bunching/Progression	Yes	Yes	Yes	Yes

Table 5: Summary of Transit Scenarios Evaluated with Simulation Model, Continued

Parameter	Scenario 6	Scenario 7	Scenario 8	Scenario 9
2 or 4 Lane Operation	2	4	4	4
2 or 3 Bus Boarding Island	3	3	2	3
Signal Timing	Existing	Existing	50% Green	50% Green
Center Lane Auto Volumes	5% of Existing	80% of Existing	Existing	Existing
Transit Vehicle Dwell Time	Existing + 10%	Existing + 10%	Existing	Existing + 10%
Dwell Time Std. Deviation	Existing + 25%	Existing + 25%	Existing	Existing + 25%
Bus Bunching/Progression	Yes	Yes	Yes	Yes

Parameter	Scenario 10	Scenario 11	Scenario 12	Scenario 13
2 or 4 Lane Operation	4	2	4	4
2 or 3 Bus Boarding Island	2	4	2	2
Signal Timing	50% Green	50% Green	Existing	Existing
Center Lane Auto Volumes	50% of Existing	50% of Existing	Existing	Existing
Transit Vehicle Dwell Time	Existing	Existing + 10%	75% of Existing	Existing
Dwell Time Std. Deviation	Existing	Existing + 25%	Existing	Zero
Bus Bunching/Progression	Yes	Yes	Yes	Yes

Eight of the 13 scenarios were selected for further analysis. Table 6 summarizes each of these option's potential for improving transit travel time along eastbound (inbound) Market Street during the a.m. peak hour and along westbound (outbound) Market Street during the p.m. peak hour. Travel time savings shown in the table assume the entire length of Market Street between Van Ness and First Street. Estimated center lane queuing at the study intersections/center boarding islands is shown in Attachment C.

Table 6: Transit Travel Time Savings for Selected Scenarios

Scenario		Inbound – AM Peak Hour		Outbound – PM Peak Hour	
"Building Block" Theme	No.	Seconds	Percent	Seconds	Percent
Reduce Auto Volumes	3	25	6%	60	9%
Extend Boarding Islands	4	15	4%	110	16%
2-Lane Operation & Extend Boarding Islands	6	35	9%	130	19%
Reduce Auto Volumes & Extend Boarding Islands	7	30	7%	125	18%
Change Traffic Signal Timing	8	100	25%	165	24%
2-Lane Operation & Change Signal Timing	11	55	14%	65	9%
Reduce Transit Dwell Time	12	80	20%	130	19%
2-Lane Operation, Extend Boarding Islands & Change Signal Timing	14	100	25%	185	27%

As shown in Table 6, the greatest single "building block" that would improve transit travel times is modifying the traffic signal timing to provide more green time along Market Street. Reducing dwell times (further discussed under "Other Considerations") would also significantly reduce transit travel times. Reducing automobile volumes, extending boarding islands, and providing 2-lane transit operations would also substantially reduce transit travel times and improve transit reliability.

Boarding Island Demand and Capacity Analysis

This section of the memorandum evaluates transit boarding island loads against capacity for several transit scenarios.

The "maximum peak" population on a boarding island includes not only passengers waiting to board a transit vehicle, but also departing passengers, who mingle with those waiting to board for a brief period of time. In calculating the peak conditions on the boarding islands, peak observed number of patrons waiting on the island to board a bus was included, along with passengers alighting simultaneously from two buses (the maximum that can fit on the approximately 100-foot long islands). This peak condition exists only momentarily, as most alighting passengers quickly leave the island.

Peak conditions were calculated by adding the highest observed waiting population on the island to the highest two alighting loads from unique bus routes. For the "merged peak" the highest number of passengers observed waiting at the curb and the island was combined with the two highest alighting loads from unique bus routes. This provides a conservative estimate of the maximum number of passengers on the island at one time, derived from observed data.

Three boarding island population level scenarios were evaluated: existing, recovery and growth conditions. Existing population levels were based on the surveyed data previously discussed. Recovery conditions recognize that sometimes service disturbances result in higher bus bunching or volumes along segments of Market Street, temporarily increasing the population levels on boarding islands. For the recovery scenarios, a 50% increase in passenger levels over existing conditions was assumed. Finally, a growth scenario was evaluated. The growth condition assumes that with improved transit travel times and reliability, transit ridership would increase. The growth scenario assumes a 12% increase in passenger levels over existing conditions.

Tables 7, 8 and 9 show the percent of capacity used by this population, given a standard of seven square feet per person on the platform under existing, recovery and growth conditions.

Table 7: Peak Platform Loads with Existing Platform Lengths

Location	Existing Peak Population	Merged Peak Population	Available Platform Area	Area Required: Existing Population	Existing Capacity Utilized	Area Required: Merged Population	Merged Capacity Utilized
4th Street Inbound	24	27	289 s.f.	168 s.f.	58%	189 s.f.	65%
1st Street Inbound	35	48	368 s.f.	245 s.f.	67%	336 s.f.	91%
Powell Outbound	40	57	303 s.f.	280 s.f.	92%	399 s.f.	132%
Sansome/Mont. Outbound	20	50	300 s.f.	140 s.f.	47%	350 s.f.	117%

Table 8: Peak Platform Loads with Existing Platform Lengths – Recovery Scenario

Location	Existing Peak Population	Merged Peak Population	Available Platform Area	Area Required: Existing Population	Existing Capacity Utilized	Area Required: Merged Population	Merged Capacity Utilized
4th Street Inbound	36	41	289 s.f.	252	87%	284 s.f.	98%
1st Street Inbound	53	72	368 s.f.	368	100%	504 s.f.	137%
Powell Outbound	60	86	303 s.f.	420	139%	599 s.f.	198%
Sansome/Mont. Outbound	30	75	300 s.f.	210	70%	525 s.f.	175%

Table 9: Peak Platform Loads with Existing Platform Lengths – Growth Scenario

Location	Existing Peak Population	Merged Peak Population	Available Platform Area	Area Required: Existing Population	Existing Capacity Utilized	Area Required: Merged Population	Merged Capacity Utilized
4th Street Inbound	27	30	289 s.f.	188	65%	212 s.f.	73%
1st Street Inbound	39	54	368 s.f.	274	75%	376 s.f.	102%
Powell Outbound	45	64	303 s.f.	314	103%	447 s.f.	147%
Sansome/Mont. Outbound	22	56	300 s.f.	157	52%	392 s.f.	131%

Based on these findings, there is sufficient space on the center boarding islands for MUNI patrons to wait safely to catch their buses under existing, non-recovery conditions only. Under a consolidated operations scenario, boarding island space is insufficient in the outbound direction during the p.m. peak. Under recovery conditions, when it is assumed that an additional 50% of existing passengers may be waiting on the boarding island for a vehicle to arrive, boarding island capacities are exceeded under existing conditions and for the consolidated operations scenario in both the inbound and outbound directions. The situation is similar under an assumed growth scenario that would result in a 12% increase in passengers, although only the capacity of the Powell Street island would be exceeded under existing transit operations.

Although predicting growth in transit ridership is somewhat less certain, recovery conditions are not rare on Market Street. Street delays from a variety of sources virtually ensure at least brief periods of recovery operations on a daily basis. Therefore, consideration to increasing the platform areas at the most crowded platforms, particularly in the outbound direction, should be a part of any plan for a consolidated center lane operation on Market Street.

The following tables examine the effects on boarding island capacity from an extension of the boarding islands to accommodate three vehicles instead of two. This would increase the area of each island by approximately 50%. As shown in the tables, extending the length of the boarding islands would alleviate nearly all of the capacity problems identified previously. Recovery conditions under consolidated transit operations would still be a problem (in terms of boarding island capacity) in the outbound direction, however (see Table 11).

Table 10: Peak Platform Loads with Extended Platforms

Location	Existing Peak Population	Merged Peak Population	Available Platform Area	Area Required: Existing Population	Existing Capacity Utilized	Area Required: Merged Population	Merged Capacity Utilized
4th Street Inbound	24	27	433	168	39%	189	44%
1st Street Inbound	35	48	552	245	44%	336	61%
Powell Outbound	40	57	455	280	62%	399	88%
Sansome/Mont. Outbound	20	50	450	140	31%	350	78%

Table 11: Peak Platform Loads with Extended Platforms – Recovery Scenario

Location	Existing Peak Population	Merged Peak Population	Available Platform Area	Area Required: Existing Population	Existing Capacity Utilized	Area Required: Merged Population	Merged Capacity Utilized
4th Street Inbound	36	41	433	252	58%	284	65%
1st Street Inbound	53	72	552	368	67%	504	91%
Powell Outbound	60	86	455	420	92%	599	132%
Sansome/Mont. Outbound	30	75	450	210	47%	525	117%

Table 12: Peak Platform Loads with Extended Platforms – Growth Scenario

Location	Existing Peak Population	Merged Peak Population	Available Platform Area	Area Required: Existing Population	Existing Capacity Utilized	Area Required: Merged Population	Merged Capacity Utilized
4th Street Inbound	27	30	433	188	43%	212	49%
1st Street Inbound	39	54	552	274	50%	376	68%
Powell Outbound	45	64	455	314	69%	447	98%
Sansome/Mont. Outbound	22	56	450	157	35%	392	87%

Table 13 summarizes the percentage of boarding island capacity that would be utilized under each of the proposed operational scenarios shown in Table 6. The scenario in which operations are consolidated into two lanes but without extending boarding islands is the only scenario in which boarding island capacity would be insufficient since that scenario consolidates transit operations into the center lane but does not include extension of the boarding islands.

Table 13: Summary of Boarding Island Capacity Utilized under Each Operational Scenario

Location	Reduced Auto Volumes	Longer Islands	2-Lane Operation, Longer Islands	Reduced Auto Volumes, Longer Islands
4th Street Inbound	58%	39%	44%	39%
1st Street Inbound	67%	44%	61%	44%
Powell Outbound	92%	62%	88%	62%
Sansome/Mont. Outbound	47%	31%	78%	31%

Location	Change Signal Timing	2-Lane Operation, Change Signal Timing	Reduced Dwell Time	2-Lane Operations, Longer Islands, Change Signal Timing
4th Street Inbound	58%	65%	58%	44%
1st Street Inbound	67%	91%	67%	61%
Powell Outbound	92%	132%	92%	88%
Sansome/Mont. Outbound	47%	117%	47%	78%

Impacts to Automobile Traffic

Two of the transit "building blocks" would impact automobile traffic. Extending the duration of the green light for Market Street traffic would reduce the amount of green time for cross-street movements, thereby increasing cross-street delays and vehicle queuing. Extending the transit-only lane easterly would prohibit automobiles from using the existing mixed-use lane, thereby increasing the amount of automotive traffic in the curb lanes.

The following steps were undertaken to estimate the effects to cross-street traffic of extending green time on Market Street:

1) Five critical intersections on Market Street were identified for the a.m. and p.m. peak hours. These intersections represented the locations with the most transit congestion and associated delay. Market Street's intersections with 1st, 2nd, 3rd, 4th, and 7th Streets were evaluated for a.m. peak hour operations and its intersections with Front, Montgomery, Kearny, Stockton, and Cyril Magnin Streets were evaluated for p.m. peak hour operations.

2) The City's 1999 weekday a.m. and p.m. peak hour Synchro traffic operations models contain intersection turning movement counts and traffic signal timing for each study intersection along Market Street. Field observations were conducted to verify (on a spot-check basis) signal timings, lane geometry, lane utilization factors, and right-turn/pedestrian influence factors.

3) Observations indicate that at locations where there is no transit-only lane, approximately 70% of all traffic uses the curb lane and 30% uses the center lane. This high concentration of traffic in the right-hand lane is likely due to driver uncertainty regarding center lane restrictions and the high levels of transit vehicles making stops in the center lane. Further, observations indicated that at locations where there is a "transit only" center lane, approximately 5% of traffic violates

the center lane restriction. Therefore, the lane utilization factors were adjusted accordingly in the Synchro models.

4) One of the key elements of vehicular circulation on Market Street is the heavy pedestrian volume. To verify their influence on intersection capacity, field observations were conducted to review the capacity at intersections for vehicles making right turns across heavy pedestrian volumes. These observations indicated that pedestrian influence factors were just over 0.5, meaning that pedestrian volumes often reduced the capacities of right-turn movements by half of their theoretical saturation flow capacities. In many cases, the Highway Capacity Methodology for calculating pedestrian saturation flow capacities appeared to underestimate the pedestrian influence, producing influence factors between 0.9 and 1.0. Therefore, a compromise between the HCM methodology and field observations was made, with pedestrian/bicycle influence factors adjusted to 0.75 in appropriate locations.

5) Delay, volume-to-capacity ratios, and queues were calculated for existing conditions for the study intersections. Finally, the same information was calculated for conditions with a minimum green time on Market Street of 30 seconds.

The results indicate that several of the critical intersections currently maintain splits greater than 30 seconds for Market Street. As shown in Table 14, of those that do not, all but two currently operate at LOS E or F. Existing operational deficiencies at these intersections would be worsened by decreasing the cross-street green time at all but three of the ten study intersections.

Two intersections with Market Street splits lower than 30 seconds currently operate at acceptable LOS B in the a.m. and p.m. peak hours. Increasing the Market Street green time at 7th Street would actually improve the intersection's operations overall during the a.m. peak hour, but would slightly increase average delay to traffic on 7th Street. In the p.m. peak hour, increasing the green time at Cyril Magnin by 1.5 seconds would have a negligible effect to both intersection traffic overall and cross-street traffic.

The following steps were undertaken to evaluate the impacts to automobiles associated with extending the transit-only lane easterly, thereby increasing the amount of automotive traffic in the curb lanes.

1) The same intersections were assessed for this task as in the previous task, and the same assumptions for transit lane violation rate, lane utilization, and pedestrian influence factors were used.

2) The existing conditions of the intersections (excluding center lane operations on Market) were evaluated similar to Step 5 above. Delays, volume-to-capacity ratios, and queues were reported for the curb lane for eastbound and westbound Market Street during the a.m. and p.m. peak hours.

TABLE 14

Market Street Intersection Operations
Existing Splits vs. 50-50 Splits

Cross Street	Existing Split (sec)		Existing Conditions					50-50 Splits				
			Delay / LOS		V/C Ratio		Cross-Street	Delay / LOS		V/C Ratio		Cross-Street
	Market	Cross Street	Intersection	Cross-Street [1]	Intersection	Cross-Street [1]	Queue [2]	Intersection	Cross-Street [1]	Intersection	Cross-Street [1]	Queue [2]
AM Peak Hour												
1st Street	38.5	21.5	>100 / F [3]	>100 / F	0.77	1.40	463 [4]	N/A [5]	N/A	N/A	N/A	N/A
2nd Street	40	20	10.7 / B	27.5 / C	0.68	0.70	39	N/A	N/A	N/A	N/A	N/A
3rd Street	31	29	92.0 / F	>100 / F	0.88	1.23	404 [4]	N/A	N/A	N/A	N/A	N/A
4th Street	23	37	>100 / F	>100 / F	1.06	1.31	400 [4]	>100 / F	>100 / F	1.05	1.63	435 [4]
7th Street	27	33	13.7 / B	4.3 / A	0.54	0.41	27	12.1 / B	5.6 / A	0.54	0.46	66
PM Peak Hour												
Front	26	34	55.7 / E	84.5 / F	0.89	1.16	544 [4]	98.6 / F	>100 / F	0.89	1.32	584 [4]
Montgomery	30	30	12.7 / B	17.1 / B	0.72	0.78	211 [4]	N/A	N/A	N/A	N/A	N/A
Kearney	31	29	99.7 / F	>100 / F	0.88	1.26	386 [4]	N/A	N/A	N/A	N/A	N/A
Stockton	23	37	>100 / F	>100 / F	1.34	1.77	344 [4]	>100 / F	>100 / F	1.34	2.21	368 [4]
Cyril Magnin	28.5	31.5	14.7 / B	9.1 / A	0.76	0.74	246	14.2 / B	10.9 / B	0.76	0.78	252

Notes:

[1] Cross-street LOS ratio for two-way cross-streets obtained by taking a weighted average of approach delays. V/C ratio for cross-streets reported for critical cross-street movement.

[2] Maximum 95th percentile queue reported, in feet, for cross-street based on HCM 2000 Methodology

[3] HCM Calculation of vehicular delay is not accurate when delay is geater than 100 seconds per vehicle.

[4] 95th percentile volume exceeds capacity, queue may be longer

[5] Intersections that already provide more than 30 seconds for Market Street were not adjusted in this analysis.

3) A second scenario was evaluated assuming that Market Street vehicular traffic would be reduced as a result of turn restrictions and/or provision of improved wayfinding signage. It was assumed that peak hour automobile volumes would be reduced by 35%, consistent with the findings of the automobile origin-destination and turn restriction analysis conducted as a part of the Market Street Study. MUNI transit volumes, based on printed timetables, were calculated for the center and curb lanes at each of the study intersections. A 35% reduction was applied to the remaining traffic. Then, the MUNI transit volumes were added back to the total. Delays, volume-to-capacity ratios, and queues were reported for the curb lane for eastbound and westbound Market Street during the a.m. and p.m. peak hours.

4) A third scenario evaluated existing conditions without turn restrictions (using 100% of existing traffic volumes), but assumed that the center transit only lane would be extended along all Market Street and all transit would move to the center lane. The total of calculated MUNI volumes were subtracted from the total through traffic on Market Street. Then, assuming a 5% violation of the transit only lane, 95% of the total non-MUNI traffic volumes were assigned to the curb lane. Delays, volume-to-capacity ratios, and queues were reported for the curb lane for eastbound and westbound Market Street during the a.m. and p.m. peak hours.

5) A final and fourth scenario evaluated conditions with both the center transit lane extension (and associated migration of all MUNI lines to the center lane) and vehicular turn restrictions. Thus, since only non-MUNI vehicles were in the curb lane, a 35% reduction was applied to the curb lane volumes identified in the previous step. Delays, volume-to-capacity ratios, and queues were reported for the curb lane for eastbound and westbound Market Street during the a.m. and p.m. peak hours.

The results of the analysis, as shown in Table 15, compare the operations of the Market Street curb lane under four scenarios described above. All curb lane operations studied appear to provide acceptable (LOS D or better) levels of service, in their respective peak hours, based on the HCM methodology, although some do experience long queues. Reducing vehicular traffic by 35% has the predictable result of reducing delays and queue lengths. Moving all transit to the center lane and all vehicular traffic to the curb lane would result in exacerbating delays and queues, although based on this analysis, none of the curb lanes would operate below LOS D during the peak hours. Adding vehicular reductions would mitigate some of the deteriorations to curb-lane operations that may be caused by extending the transit-only lane.

TABLE 15

Market Street Curb Lane Operations

Cross Street	Existing Conditions						Existing Conditions with 35% Traffic Reduction						Transit Lane Extension and All Transit in Center Lane						Transit Lane Extension and All Transit in Center Lane and 35% Reduction in Traffic					
	EB Market [1]			WB Market			EB Market			WB Market			EB Market			WB Market			EB Market			WB Market		
	Delay / LOS	V/C	Queue	Delay / LOS	V/C	Queue	Delay / LOS	V/C	Queue	Delay / LOS	V/C	Queue	Delay / LOS	V/C	Queue	Delay / LOS	V/C	Queue	Delay / LOS	V/C	Queue	Delay / LOS	V/C	Queue
AM Peak Hour																								
1st Street	14.1 / B	0.45	106	8.0 / A	0.18	75	9.9 / A	0.32	87	7.3 / A	0.13	26	19.3 / B	0.66	221	7.3 / A	0.13	26	11.9 / B	0.43	133	6.6 / A	0.08	19
2nd Street	13.9 / B	0.79	259 [2]	7.9 / A	0.16	58	7.0 / A	0.52	67	6.7 / A	0.11	38	22.4 / C	0.91	254 [2]	6.9 / A	0.15	46	7.9 / A	0.59	87	5.6 / A	0.09	28
3rd Street	16.9 / B	0.61	259	4.9 / A	0.15	25	11.5 / B	0.40	92	5.3 / A	0.11	22	22.3 / C	0.74	323 [2]	4.9 / A	0.12	21	13.3 / B	0.48	113	5.3 / A	0.08	17
4th Street [3]	34.9 / C	0.69	152 [2]	26.8 / C	0.33	133	29.1 / C	0.45	122	25.8 / C	0.23	101	35.3 / D	0.69	189	27.4 / C	0.34	139	29.3 / C	0.45	135	25.8 / C	0.22	99
7th Street	34.5 / C	0.71	290 [2]	5.3 / A	0.24	36	29.7 / C	0.47	211	4.8 / A	0.16	24	35.5 / D	0.75	316 [2]	6.0 / A	0.27	44	29.9 / C	0.49	215	4.9 / A	0.19	26
PM Peak Hour																								
Front	9.0 / A	0.6	47	20.7 / C	0.51	164	5.4 / A	0.42	34	18.8 / B	0.35	122	11.6 / B	0.69	52	23.8 / C	0.62	201	5.8 / A	0.45	37	19.3 / B	0.40	137
Montgomery	13.9 / B	0.79	126	5.1 / A	0.38	22	10.6 / B	0.52	85	4.7 / A	0.27	20	20.7 / C	0.93	284 [2]	4.9 / A	0.40	20	10.7 / B	0.61	100	4.4 / A	0.26	18
Kearny	16.7 / B	0.57	177	9.7 / A	0.36	89	12.1 / B	0.38	102	8.3 / A	0.25	58	21.6 / C	0.70	292	9.9 / A	0.38	95	14.1 / B	0.46	126	8.3 / A	0.25	57
Stockton [3]	34.6 / C	0.69	159 [2]	30.1 / C	0.58	212	30.2 / C	0.45	103	27.0 / C	0.40	148	34.9 / C	0.69	175	32.5 / C	0.67	242	30.6 / C	0.45	126	27.8 / C	0.44	162
Cyril Magnin	38.0 / D	0.83	307 [2]	15.4 / B	0.68	103	27.5 / C	0.55	187	6.7 / A	0.46	36	36.4 / D	0.81	289 [2]	21.8 / C	0.78	268 [2]	27.0 / C	0.52	200	7.3 / A	0.51	46

Notes:

[1] All results presented in this table refer to the curb lane operations only. Delay is reported in seconds, based on the HCM 2000 methodology. Queue Lengths are reported in feet as 95th Percentile queues.

[2] 95th percentile volume exceeds capacity, queue may be longer.

[3] Analysis of EB Market at 4th examines thru lane and right turn lane. Center thru lane is omitted.

In fact, a careful comparison between the two scenarios with the 35% traffic reduction reveals that in some locations, particularly along westbound Market Street during the a.m. peak hour, better curb lane operations would result when transit is consolidated into the center lane. This is because there are two variables between the traffic reduction scenarios. First, in the option that consolidates transit to the center lane, all vehicular traffic (except for taxis, police and the occasional violator) that previously used the center lane shifts to the curb lane to account for the extension of the transit-only restriction. Then, the bus volumes in the curb lane would be transferred into the center lane. In some cases, especially for westbound Market Street during the a.m. peak hour, the traffic volumes are low enough that moving the curb land buses to the center lane and moving the automobile traffic from the center lane to the curb lane results in very little change in the overall volumes in the curb lane. Therefore, the level-of-service does not change significantly, and in some cases slightly improves for a number of locations, between these traffic reduction scenarios.

Other Considerations

Several constraints to decreasing transit travel times and improving transit reliability using the "building blocks" previously described would need to be considered prior to implementing one or more of these measures. These include:

- Installing additional crossover wires between the center lane and curbside overhead wires on Market Street so that buses can move to the curb as needed to avoid and pass unexpected obstructions in the center lane. Currently, crossover wires exist between 3rd and 2nd Streets (curb to center) and 2nd and 1st Streets (center to curb) in the inbound direction, and between Front and Battery (center to curb) in the outbound direction. According to MUNI staff, additional crossover wires could be installed at a relatively minimal cost.

- Making all boarding islands wheelchair accessible if transit operations are consolidated into the center lane. For islands that are currently inaccessible, this will require adding curb ramps and detectable warning surfaces on the portion of the islands adjacent to crosswalks, and may also require that islands be widened so that they are at least five feet in width (from railing to opposite curb).

- Discouraging pedestrian jaywalking to extended boarding islands. Through measures such as increased enforcement and provision of signs and barriers, it may be possible to decrease the level of jaywalking.

- Decreasing transit dwell times at the boarding islands if transit operations are consolidated into the center lane and/or boarding islands are extended. Dwell times could be reduced through means such as proof-of-payment, provision of low-floor buses, and installation of real-time traveler information.

- Minimizing bicycle pinchpoints resulting from increased automobile traffic in the curb lanes. With more auto traffic in the curb lanes, bicyclists would be further challenged in traveling along Market Street. Auto volume reductions through signing and/or restricted turning movements would be beneficial, as would provision of appropriate bicycle facilities.

Conclusions

One of the goals of the Market Street Study is to decrease transit travel times and improve transit reliability. Several measures have been explored to achieve this goal. Two measures – providing improved transit-only lane enforcement and decreasing transit vehicle dwell times at transit stops – should be undertaken in the near future.

For the longer-term, four fundamental "building blocks" for improving transit performance along Market Street were studied: 1) extending the transit-only lanes, 2) extending the size of the center boarding islands, 3) increasing green light duration along Market Street, and 4) reducing the amount of automobile traffic and congestion on Market Street.

The greatest single "building block" that would improve transit travel times is modifying the traffic signal timing to provide more green time along Market Street. However, adding green time to Market Street would reduce the amount of green time available for cross-street movements. According to a traffic assessment, most cross-street movements currently operate at level-of-service E or F during the p.m. peak period.

Reducing automobile volumes, extending boarding islands, and providing two-lane transit operations – individually and in combination – would also substantially reduce transit travel times and improve transit reliability. Each of these measures would result in some impacts as well, e.g., consolidating transit into the center lanes would shift more automobiles to the curb lanes, resulting in increased congestion depending upon the resulting traffic levels.

The most significant improvements would result by combining measures, e.g., extending boarding islands, providing two-lane operations and modifying traffic signal timing.