



Crooked Street Reservation and Pricing Study

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RE: **Crooked Street Reservation and Pricing Study**
Operational Scenarios Technical Memorandum - Final

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The purpose of this document is to establish a preferred operational approach, with potential specific operational scenarios, for managing vehicle throughput and access to the Lombard Crooked Street. To this end, this document reviews potential operational approaches considered to-date for managing vehicle throughput and access to the Lombard Crooked Street and how a preferred approach was selected; outlines operational parameters and preliminary business rules for potential operational scenarios; and details potential options for user interactions with the reservation component of the preferred approach. In a subsequent document, the project team will develop a concept of operations that further refines and details how the preferred scenario is selected and may ultimately operate.

1. Study Goals

The SFCTA initiated the Lombard Crooked Street Reservation and Pricing Study with the goal of developing a solution to vehicle congestion at and around the Crooked Street with an aim towards the following goals:

- Managing pedestrian congestion
- Managing auto congestion
- Ensuring traffic safety
- Maintaining access to the “Crooked Block” (1000-1100 Lombard and adjoining streets and properties)
- Maintaining livability of the surrounding neighborhood
- Preserving tourism at a sustainable level
- Implementing a financially viable solution

As described in SFCTA’s Lombard Study: Managing Access to the “Crooked Street” Final Report (Lombard Study), adopted by the SFCTA Board in March 2017, the study goals were informed by onsite observations of traffic circulation, traffic volume counts, intercept surveys, and interviews with local residents as well as community groups and businesses. Though these different groups prioritized each of these goals differently, the 2017 study considered each of the goals to be on equal footing and analyzed prospective improvements against all seven.

For the current phase of work, the goals from the 2017 Lombard Study were brought forward, with the study team developing metrics and potential operational targets relevant to the potential implementation of a vehicle management system. **Table 1** lists seven goals and their respective metrics for effectiveness, along with minimum and ideal targets for meeting each metric. These metrics and targets served as the basis for the quantitative evaluation of alternatives conducted by SFCTA. Resident access to the “Crooked Block” was considered self-evident and therefore a metric target was not quantified.

Table 1- Project Goals and Metrics

Goal	Metric	Target	
		Minimum	Ideal
Manage pedestrian congestion	Percentage of pedestrians lingering in intersection crosswalks for excessive periods of time (i.e., crossing significantly more slowly than a typical walking speed [3 ft/s])	Less than 15 percent of pedestrians linger in crosswalks for excessive periods of time	Less than 10 percent of pedestrians linger in crosswalks for excessive periods of time
Manage automobile congestion	Time vehicle queue extends west past Larkin Street (1 block) in each hour of the week	Time vehicle queue extends past Larkin is no more than 15 min in any given hour	Vehicle queue does not extend beyond 1100 block of Lombard Street
Ensure traffic safety	Extent to which pick-ups/ drop-offs block cable cars, pedestrians/ crosswalks, or automobiles	Pick-ups and drop-offs do not block travel lanes or sidewalks more than 15 min in any given hour	All pick-ups and drop-offs do not block travel lanes or sidewalks
Maintain access to the “Crooked Block”	Residents in 1000-1100 Lombard block and adjoining properties and streets continue to have unrestricted access at all times	n/a	n/a
Maintain the livability of the surrounding neighborhood	Revenue generated	Revenue beyond operating costs greater or equal to current cost of services (PCOs, ambassadors)	Revenue beyond operating costs greater or equal to cost of expanded services such as PCOs, Police Officers, and related to manage impact of visitors on neighborhood
Preserve tourism at a sustainable level	Number of visitors per day	Number of visitors that allows the system to meet other minimum targets, given proposed improvements	Number of visitors that allows the system to meet other ideal targets, given proposed improvements
Implement a financially viable solution	Revenue generated	Revenue covers basic operations and maintenance costs of the pricing and reservations system	Revenue beyond operating costs greater or equal to cost of expanded services such as PCOs, Police Officers, and related to manage impact of visitors on neighborhood

Source: SFCTA and Arup, 2019.

Note: n/a = not applicable

2. Operational Approaches and Selection of Preferred Alternative

An outcome of the 2017 Lombard Study was identification of several short- and mid-term strategies and solutions to address the challenges of current Lombard Crooked Street operations. Identified short-term strategies include improved enforcement of existing regulations and engagement of tourism industry as partners in visitor management, while mid-term strategies with a longer lead time for completion include engineering and signage enhancements and the development and implementation of a reservation / pricing system for vehicle access. This section focuses on four potential operational approaches for that reservation / pricing system that was identified as a recommendation of the 2017 Lombard Study. These four alternatives are discussed further – 1) pricing only, 2) reservation only, 3) combined pricing plus paid reservations, and 4) paid reservations only.

Pricing Only

A pricing-only approach would seek to manage congestion by relying on a pricing mechanism to control the number of vehicles entering the Crooked Street. As identified previously in the 2017 Lombard Study, it is assumed such a system would operate all-electronically, with pricing that follows a variable scheme according to demand and time of day. Prices would be adjusted to rise and fall relative to periods of peak and off-peak congestion, and could be adjusted accordingly to historical hourly vehicle demands and flows by time of day and day of week. However, because there would be no reservation mechanism to manage vehicular congestion, this system would not limit the number of vehicles arriving to the Crooked Street, but would instead rely solely on pricing to manage overall vehicular demand.

The pricing-only scheme overall is expected to have moderate effectiveness in meeting the primary goals of the study. In terms of managing automobile congestion, while tolls would have the potential to shorten long vehicular queues entering the Crooked Street, there would be no management or limit on the number of vehicles arriving in the neighborhood before making a decision to drive the street based on the pricing at the time, leaving the potential for congestion on Lombard and nearby streets if more vehicles than there are capacity for arrive in a short period of time.

In terms of the goal of implementing a financially viable solution, the pricing only scheme could be effective in raising revenue and has the potential to cover the associated operational costs. All motorists entering the Crooked Street (with the potential exception of neighborhood residents) would pay to travel down the Crooked Block, which would enable funding of operations, enforcement of the roadway, and ongoing facility maintenance. The pricing only scheme would only be moderately effective in maintaining livability of the surrounding neighborhood, given that while pricing would generate revenue, the system may not be sustainable due to the inability to manage vehicle arrivals. The scheme could be set up to be self-sustaining financially, allowing for sufficient revenue for system upgrades. Lastly, meeting the goal of preserving tourism at a sustainable level of visitors per day would have moderate success, given that a variable pricing system may be less easily understood and friendly to tourists.

Reservation Only

A reservation-only approach would manage congestion by controlling how many vehicles would be able to enter the Crooked Street within a given time period. Under this scheme, it is assumed that there would be no fee to make a reservation. The reservation-only scheme is expected to be less effective than a pricing-only scheme in meeting the primary goals of operating the Crooked Street system, with the exception of managing automobile congestion. Motorists would be able to reserve a specific time of day to arrive and travel the street, which would facilitate management and reduction of vehicle queues leading to the Crooked Street.

In terms of the goal of implementing a financially viable solution, the reservation-only scheme would, by definition, not have an associated fee. As a result, no funds would be collected to manage the reservation system, which in turn would create an additional cost center with no obvious source of revenue to support this increased expenditure. The reservation-only scheme would only somewhat meet the goal of maintaining livability of the surrounding neighborhood, as while the system may be effective in managing the flow of vehicles on the Crooked Street, the absence of revenue generated by the reservation system would create new, additional costs to a location that is already challenging for the City to maintain in terms of enforcement and maintenance. Lastly, while the reservation-

only scheme would likely be effective in meeting the goal of preserving tourism at a sustainable level by managing tourist entries at this location, this benefit would be offset by the costliness of enforcing and maintaining the reservation system without any dedicated revenue to operate it.

Pricing Plus Paid Reservation

An alternative that combines the pricing only with paid reservations approaches was also evaluated. This concept would require motorists to pre-purchase a reservation at a set price or would allow motorists without a pre-purchased paid reservation to arrive at the Crooked Street and pay a higher, variable price. The price for motorists who arrive without a reservation would need to be high enough to ensure that the system is not compromised by too many motorists arriving without reservations, and consequently forming long vehicle queues that would delay traffic in the surrounding area, including those attempting to arrive for their pre-purchased paid reservation time. The uncertainty about whether large numbers of motorists would decide to arrive without a reservation and pay the higher price may call into question the ability of this alternative to effectively manage congestion.

From the perspective of financial viability, this alternative could raise more revenue than the paid reservation approach. However, the goals of maintaining livability and preserving tourism may be compromised as a result of allowing vehicles to arrive at any time. This could result in needing to charge exorbitant prices for those who show up without a reservation while putting at risk the enjoyment of the Crooked Street for those who do make reservations, creating a negative experience for all visitors.

Paid Reservation

A fourth scheme considered by the project team is a paid reservation system, which requires motorists to pre-purchase a reservation at a set price. In terms of collectively meeting the primary goals of the project, this scheme performs the best. Not only does this scheme have the potential to manage vehicle queueing through the reservation system, but it also has the potential to generate revenues that can go towards operating and maintaining the system and addressing the impacts of tourism on the neighborhood.

Of all four schemes, the paid reservation scheme would best meet the goal of maintaining neighborhood livability. Paid reservations provide the most flexibility to manage vehicular traffic while generating a dedicated source of revenue to maintain the system and address neighborhood impacts from tourism. This alternative has an edge over a pricing-only scheme for this specific goal, as the pricing-only scheme would be less effective in terms of managing the timing and grouping of vehicle arrivals. Lastly, in terms of preserving sustainable tourism, the paid reservation scheme would enable tourists to plan their trips in advance and substantially reduce the uncertainty of waiting in congestion to drive down the Crooked Street. Similar to the other two schemes requiring payment, depending on the pricing of the paid reservation some tourists could be deterred from visiting by car.

Qualitative Evaluation

Each of the four potential operational approaches was qualitatively evaluated against the established project goals in an initial screening exercise. During the evaluation, it was determined that the goals of managing pedestrian congestion and ensuring traffic safety were more appropriate for quantitative evaluation and were not considered at this step. **Table 1** summarizes the results of the qualitative evaluation – red shading indicates the approach did not meet the stated goal, yellow shading indicates the approach was questionable in meeting the stated goal, and green shading indicates the approach met the stated goal. As shown, the paid reservation approach was found to meet each of the goals while the other three approaches failed to meet at least one of the goals.

Table 1 – Qualitative Evaluation

Goal	Operational Approaches			
	Pricing Only	Reservation Only	Pricing & Reservation	Paid Reservation
<p>Manage Automobile Congestion</p> <p>Eliminate long queues near Lombard Street</p>	Price could shorten queues, but vehicles will still arrive unmanaged.	Vehicles are given a timed reservation, matching arrivals to the capacity of the street. Queuing and congestion will be managed.	Non-reservation price could deter arrivals without a reservation, but vehicles will still arrive unmanaged. Unmanaged arrivals could undermine the efficacy of the reservation component	Vehicles are given a timed reservation, matching arrivals to the capacity of the street. Queuing and congestion will be managed.
<p>Implement a Financially Viable Solution</p> <p>Cover the costs of existing staffing at the site</p>	All vehicles would pay, providing funds for existing site operations, enforcement and maintenance.	No funds would be collected for site operations, enforcement, and maintenance.	All vehicles would pay, providing funds for existing site operations, enforcement and maintenance.	All vehicles would pay, providing funds for existing site operations, enforcement and maintenance.
<p>Maintain the Livability of the Surrounding Neighborhood</p> <p>Create a self-sustaining system and generate revenue for upgrades</p>	Revenue would be generated, but livability could be compromised due to uncertainty about managing vehicle arrivals and reduction in congestion.	While the system may manage vehicle arrivals, the absence of revenue would not provide for further investments in livability improvements.	Revenue would be generated, but livability could be compromised due to uncertainty about managing vehicle arrivals and reduction in congestion.	Paid reservations provide the most flexibility to manage vehicle arrivals while generating additional revenue for investments in livability improvements.
<p>Preserve Tourism at a Sustainable Level</p> <p>Preserve the number of visitors per day</p>	Not having the ability to plan a trip in advance may not be the friendliest option for tourism and the price would likely need to be high to deter visitation above capacity, but revenue would be generated to fund resources for the site.	Visitors can reserve a time and plan their trip in advance, but no revenue would be generated to fund resources for the site.	Allowing visitors to arrive without a reservation could compromise the integrity of the reservation system and create confusing rules, regulations, and expectations for visitors.	Visitors will be provided with a clear set of expectations and be able to plan trips in advance. Revenue would be generated to fund resources for the site.

As a result of the qualitative evaluation, the paid reservation scheme was selected as the preferred approach, given the scheme's potential to significantly reduce automobile queueing and congestion entering the Crooked Street through a combination of controlled access via reservations that generated revenue to support the costs of administering the system and managing the broader impacts of the Crooked Street. Further, this scheme enables a future operator to raise revenue that would allow for a self-sustaining mechanism to fund ongoing system operations and maintenance. In the next section, scenarios detailing preliminary operational parameters and business rules for the preferred approach are discussed.

3. Preferred Approach – Preliminary Operational Parameters

This section defines recommended operational parameters for the scenarios under the paid reservation approach. The recommendations were informed by data collected by SFCTA, including vehicle counts, queue lengths, and intercept surveys. The recommendations focus on system hours of operation; pricing of reservations relative to hours and days of the week; number of reservation slots and intervals for each timeslot; and business rule variations relative to residents, waived tolls, and other demand-related considerations. This section defines two scenarios that were developed for quantitative evaluation based on the recommended operational parameters and business rules.

The following sections describe the rationale for the recommended operational parameters.

Hours of Operation

Review of queueing data collected by SFCTA revealed that vehicle queues generally start each day around 10:00 a.m. and dissipate by approximately 8:00 p.m. To proactively manage expected vehicle arrivals that may occur on the shoulders (before and after) of the daily peak 10-hour period, it is recommended to initiate daily system operation one hour before the morning queues and one hour after evening queues dissipate. This results in daily operations between 9:00 a.m. and 9:00 p.m.

Seasonal adjustments to the hours of operation may need to be considered. During the period when daylight savings time ends (November through March) and hours of daylight accordingly reduce, the necessary daily time window for the pricing and reservation system could also be reduced given the fact that peak vehicular activity at the Crooked Street generally occurs during daylight hours. Additional seasonal vehicular queueing data would be necessary to confirm whether the 9:00 a.m. and 9:00 p.m. daily pricing and reservation window could be reduced during the November through March period.

Reservation Pricing

Vehicle count and queuing data collected by SFCTA revealed generally higher demand on Saturday through Monday¹ as compared to Tuesday through Friday. Furthermore, Saturday through Monday queue lengths are nearly double the maximum queue lengths experienced on Tuesdays through Fridays, as shown in the average weekly profile in **Figure 1** for the three blocks upstream of the Crooked Street entrance between Hyde Street and Van Ness Avenue. The 2017 Lombard Study also identified that 97% of visitors to the Crooked Street are either “very” or “somewhat” flexible in the time that they could visit the street. Given these data, an initial recommendation is to set a higher price for reservations on a Saturday, Sunday and holidays and allow a lower cost for reservations made for all other days (e.g. Mondays through Fridays) to encourage visitors who can shift their day of visit to a less crowded day to do so.

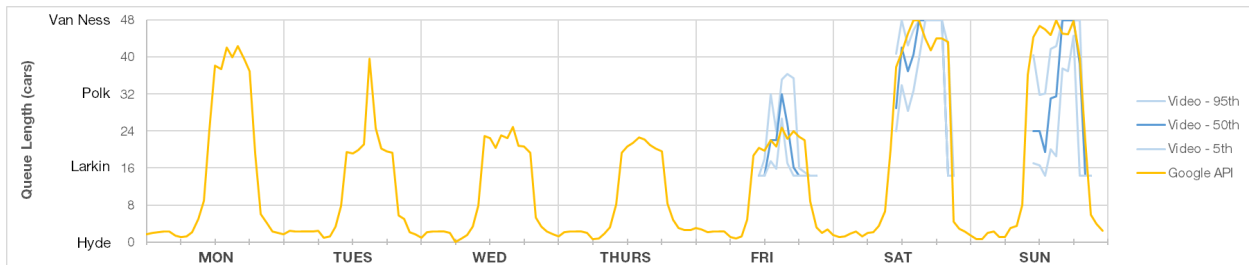


Figure 1: Car Queuing Upstream of the Crooked Street (Source: SFCTA and Arup, January 2019)

To initiate and inform the process of setting a specific price relative to day of week and time of day, there are two pieces of information that may be valuable. First, willingness-to-pay data collected by the SFCTA in 2018 could be paired with estimates of unconstrained vehicle demand to aid the balancing of overall supply and demand. Second, an estimate of operating costs for the reservation system could help in setting the daily and hourly price, while furthering the goal of cost recovery and creating a self-sustaining system operation.

Daily Reservation Slots

As illustrated in **Figure 2**, daily observed vehicle volumes indicate that the vehicle processing capacity of the Crooked Street is around 220 vehicles per hour (vph). To account for statistical uncertainty, it is anticipated that the arrival rate to the Crooked Street would need to be no greater than 210 vph in order to maintain an average queue length of eight vehicles, which is half of the estimated 16-vehicle queue length that can be accommodated along the upstream, eastbound Lombard block between Hyde and Larkin Streets approaching the Crooked Street.

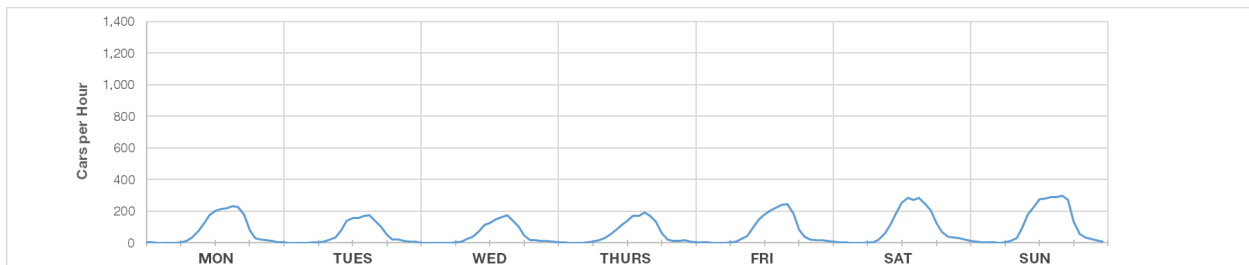


Figure 2: Crooked Street Average Weekly Traffic Profile (Source: SFCTA and Arup, January 2019)

For each motorist using the system, a 30-minute time slot is proposed that allows access to the Crooked Street and a sufficient time window to arrive (allowing for early and late arrivals) and travel down the street. Further, to avoid clustering of vehicle arrivals, reserved slot start times are proposed to be staggered every 15 minutes. In order to keep arrivals below 210 vph, a maximum of 52 reservation slots per 30-minute interval could be offered. However, in practice it can be reasonably expected that some guests would either arrive outside of their assigned 30-minute time interval or otherwise be exempt from making a reservation, such as residents of the Crooked Street. As an initial

¹ SFCTA data was collected over the Labor Day holiday weekend in 2018; increased visitation on Monday is likely attributable to this weekend.

assumption, approximately 20 percent of vehicle arrivals are assumed to fall under these arrival conditions. To accommodate early, late and exempt arrivals, it is recommended that no more than 40 reservation slots be made available per rolling 30-minute time interval.

Enforcement

A credible enforcement approach must accompany the implementation of a reservation system to minimize abuse of the system and resulting degradation in the ability to manage vehicle demand. Ideally, the enforcement approach would include some sort of penalty or fine set at a sufficiently high level to dissuade noncompliance with the paid reservation system. A review of available data and comparable enforcement will be conducted in the next phase of the study to determine a recommendation for this penalty. For the purposes of this analysis, compliance with the rules of the system are assumed.

Based on the recommended operational parameters described above, the following two scenarios are recommended for quantitative evaluation.

Scenario 1 (24/7 Operation)

Feedback from community members during the creation of the 2017 Lombard Study indicated a desire for a potential reservation and/or pricing system to operate at all times. Scenario 1 was developed in response to this community feedback.

Under Scenario 1, the paid reservation system would operate 24 hours a day and seven days per week, with a reservation price of \$5 all day. 24-hour operation would ensure the Crooked Street entry is managed at all times. A total of 40 reservation slots would be offered per 30-minute time interval, with time intervals staggered every 15 minutes. For example, between 1:00 p.m. and 2:00 p.m. on any given day, 40 reservation slots would be offered for each of the following intervals: 12:45 p.m. to 1:15 p.m., 1:00 p.m. to 1:30 p.m., 1:15 p.m. to 1:45 p.m., 1:30 p.m. to 2:00 p.m., and 1:45 p.m. to 2:15 p.m. The 30-minute time interval for each visit is proposed, as it allows a sufficient time window for visitors driving to arrive at the Crooked Street entrance (while also allowing for early and late arrivals) and complete their travel down the street. Further, the staggering of time intervals every 15 minutes avoids clustering of vehicle arrivals.

Scenario 2 (9:00 am to 9:00 pm Daily Operation)

Scenario 2 is based on the recommended operational parameters discussed earlier in this memorandum, as developed through a review of data collected through traffic counts, queuing observations, and surveys of visitors in Summer 2018. This scenario represents an intervention only when indicated to be necessary by current operational data.

Scenario 2 would operate the same as Scenario 1 in terms of the number of reservation slots offered, 30-minute visitation interval, and staggering of intervals every 15 minutes. However, under Scenario 2 the hours of operation of the paid reservation system and the price of reservations would vary.

Under Scenario 2, the system would operate between 9:00 a.m. and 9:00 p.m., seven days per week. Remaining off hours each day would allow free, unreserved access to the Crooked Street. The daily hours of system operation are based review of historical data, which revealed that vehicles using the Crooked Street generally beginning queuing each day around 10:00 a.m., with queues dissipating by approximately 8:00 p.m. The intent of initiating daily system operation one hour before the morning queues and one hour after evening queues dissipate is to proactively manage expected vehicle arrivals that may occur on the shoulders (before and after) of the daily peak 12-hour period, before there is significant vehicle accumulation at the upstream approach to the Crooked Street.

Further, the system under Scenario 2 would price reservations based on typical peak days of usage. Review of historical data indicates that the approach to the Crooked Street experiences the highest vehicle queue lengths weekly during Saturdays, Sundays, and holidays. Furthermore, Saturday, Sunday, and holiday vehicle queue lengths are nearly double the maximum queue lengths experienced on regular weekdays. As an initial measure, the price

for a reservation under this scenario would be set at \$10 on Saturdays, Sundays, and holidays, and \$5 all other days of the week. The intent of this price differential is to encourage drivers to visit on off-peak days when the demand is lower, i.e. Tuesdays through Fridays, or to visit the Crooked Street by another mode such as walking, bicycling, and transit if visiting on the highest demand days.

Table 2 summarizes and compares the two system operational scenarios being considered.

Table 2: Scenario Comparison

	Scenarios		
	Existing Conditions	Scenario 1	Scenario 2
Hours of Paid Reservation Operation	No Reservation Required	24 hours / 7 days per week	9:00 a.m. – 9:00 p.m. every day
Reservation Price	No Reservation Required	\$5 All Times	\$10 Sat, Sun, holidays \$5 All Other Times
Reservation Slots	Not Applicable	40 reservations per 30-minute interval	40 reservations per 30-minute interval

Operational Parameter Variations

Based on discussions with SFCTA staff and public outreach conducted to-date, additional consideration and analysis of some variations to the above base operational parameters for both scenarios may be warranted as described below.

First, a reservation exemption for Crooked Street residents and visitors should be considered for both scenarios under the principle that local residents and their guests should be able to continue to enjoy unconstrained access to their properties that rely on the Crooked Street for connectivity to the greater City street system. Generally speaking, the amount of vehicular congestion contributed by Crooked Street residents based on traffic data collected to date is minimal relative to the current unconstrained vehicular volumes along the street segment.

A second potential variation from both scenarios’ base operation would be further exemptions for all City of San Francisco residents. In this variation, San Francisco residents would be allowed to make a no cost reservation to travel the Crooked Street during any time of day or day of week. According to the 2017 Lombard Study, it is estimated that approximately 7 percent of daily vehicles using the Crooked Street are registered in San Francisco, and SFCTA data collected in 2018 revealed that 4 percent of vehicles surveyed are City of San Francisco residents. An analysis of a business rule variation of San Francisco resident exemption from a paid reservation against the base scenario should be conducted, to understand the implications and tradeoffs relative to the overall system, its operating cost, and relative traffic congestion.

A third variation relates to the number of time slots available to visitors. An important consideration relative to setting the number of daily time slots is unconstrained demand. Once the system under either scenario is in operation, if it is found that vehicle arrivals are much higher than the initially set number of reservation slots (40 slots every 30 minutes), the method by which time slots are assigned could be refined (e.g., increasing the duration of the time intervals or reducing the amount of overlap between time intervals). Furthermore, additional data could be collected on the guest duration of stay while the Crooked Street paid reservation system is in operation. This could inform whether the 30-minute window remains valid based on observable data on guests’ early and late arrivals, how long they take to drive the Crooked Street, and whether that time could be shortened to accommodate more daily reservation time slots.

4. Scenario Performance

SFCTA and Arup staff conducted an analysis of performance of the two scenarios as compared to existing conditions, defined as no change to the current generally unconstrained access to the Crooked Street. The results of this analysis are detailed in a separate technical memo, while **Table 3** summarizes the results of the analysis, showing existing

conditions and how the two above-defined proposed toll reservation scenarios could be expected to perform against the project goals. Green shading indicates that a scenario meets the project metric target and therefore fulfills a particular project goal. Red shading indicates that scenario does not meet the project metric target to fulfill a particular project goal. Yellow shading indicates that a project goal has no specific corresponding project metric target for the project scenario to meet. The goal of maintaining access to the ‘Crooked Block’ was not considerable quantifiable and thus was not pursued further in this performance analysis.

Table 3: Scenario Performance

Goal	Metric	Target		Expected Performance		
		Minimum	Ideal	Existing	Scenario 1	Scenario 2
Manage automobile congestion	Time vehicle queue extends west past Larkin Street (1 block) in each hour of the week	Time vehicle queue extends past Larkin is no more than 15 min in any given hour	Vehicle queue does not extend beyond 1100 block of Lombard Street	Vehicle queue extends upstream of Larkin Street at least six hours per day each day of the week.	Weekly peak hour arrival flow (weekend afternoons) is 175 veh/hr; average queue will not reach Larkin Street. For average arrival flows less than 210 veh/hr, average queue not expected to extend more than 8 vehicles.)	Weekly peak hour arrival flow (weekend afternoons) is 160 veh/hr; average queue will not reach Larkin Street. For average arrival flows less than 210 veh/hr, average queue not expected to extend more than 8 vehicles.)
Maintain the livability of the surrounding neighborhood	Revenue generated	Revenue beyond operating costs greater or equal to current cost of services (PCOs, ambassadors)	Revenue beyond operating costs greater or equal to cost of expanded services such as PCOs, Police Officers, and related to manage impact of visitors on neighborhood	No revenue generated.	\$37,000 gross revenue generated per week. Operating costs to be determined in a future phase of this study.	\$42,000 gross revenue generated per week. Operating costs to be determined in a future phase of this study.
Manage pedestrian congestion	Percentage of pedestrians lingering in intersection crosswalks for excessive periods of time (i.e., crossing significantly more slowly than a typical walking speed [3 ft/s])	Less than 15 percent of pedestrians linger in crosswalks for excessive periods of time	Less than 10 percent of pedestrians linger in crosswalks for excessive periods of time	At Lombard Street & Hyde Street, only approximately 15% of pedestrians occupy the crosswalks linger in the crosswalks. At Lombard Street & Leavenworth Street, however, over 45% of pedestrians linger in the crosswalk.	Without interventions at the two study intersections, 15% and 45% of pedestrians expected to linger in crosswalks at Lombard & Hyde and Lombard & Leavenworth intersections, respectively. Also, greater volumes of pedestrians overall are expected. In weekly peak hour (Saturday afternoon), 290 visitors divert from driving Crooked Street to visiting as pedestrian, thereby adding to overall crowding of pedestrian space.	Without interventions at the two study intersections, 15% and 45% of pedestrians expected to linger in crosswalks at Lombard & Hyde and Lombard & Leavenworth intersections, respectively. Also, greater volumes of pedestrians overall are expected. In weekly peak hour (Saturday afternoon), 410 visitors divert from driving Crooked Street to visiting as pedestrian, thereby adding to overall crowding of pedestrian space.

Goal	Metric	Target		Expected Performance		
		Minimum	Ideal	Existing	Scenario 1	Scenario 2
Ensure traffic safety	Extent to which pick-ups/ drop-offs block cable cars, pedestrians/ crosswalks, or automobiles	Pick-ups and drop-offs do not block travel lanes or sidewalks more than 15 min in any given hour	All pick-ups and drop-offs do not block travel lanes or sidewalks	Pick-up / drop-off activity frequently obstructs pedestrians, cable car, and other car traffic.	In weekly peak hour (weekend afternoons), 70 visitors diverted from driving Crooked Street to visiting by getting dropped off; obstructing pick-up / drop-off activity expected to increase accordingly.	In weekly peak hour (weekend afternoons), 100 visitors diverted from driving Crooked Street to visiting by getting dropped off; obstructing pick-up / drop-off activity expected to increase accordingly.
Implement a financially viable solution	Revenue generated	Revenue covers basic operations and maintenance costs of the pricing and reservations system	Revenue beyond operating costs greater or equal to cost of expanded services such as PCOs, Police Officers, and related to manage impact of visitors on neighborhood	No revenue generated.	\$37,000 revenue generated per week. Additional costs to be developed in a future phase of this study.	\$42,000 revenue generated per week. Additional costs to be developed in a future phase of this study.
Preserve tourism at a sustainable level	Number of visitors per day	Number of visitors that allows the system to meet other minimum targets, given proposed improvements	Number of visitors that allows the system to meet other ideal targets, given proposed improvements	Presently, 21,000 people visit the Crooked Street on the average day (6,500 average daily drive visitors and 14,500 average daily walk visitors).	20,000 people will visit the Crooked Street on an average day (a five percent reduction overall to 4,000 daily drive visitors and 16,000 daily walk visitors).	20,000 people will visit the Crooked Street on an average day (a five percent reduction overall to 3,700 daily drive visitors and 16,300 daily walk visitors).

Source: SFCTA and Arup, January 2019.

Note: veh/hr = vehicles per hour

Both proposed paid reservation scenarios evaluated in **Table 3** substantially resolve the extreme car queuing on Lombard Street upstream of the Crooked Street that is present throughout most of a typical week as observed in August and October 2018. With the proposed assignment of reservation slots, queuing is estimated not to extend back to Larkin Street at any time during a typical week.

Throughout the weeks of observation, the eastern crosswalk of the intersection of Lombard Street & Leavenworth Street was observed to have a particularly high proportion of pedestrians (nearly 50 percent) lingering in the crosswalk (i.e., crossing more slowly than a benchmark of 3 feet per second). Both scenarios are estimated to increase pedestrian visitor traffic to the Crooked Street during weekend peak periods by approximately 20 percent. Without intervention, this is expected to slightly worsen the existing difficulties associated with pedestrians lingering in crosswalks, unnecessarily blocking car traffic, and possibly endangering themselves or others. Potential interventions to accommodate elevated pedestrian volumes include further enforcement of pedestrian crossings with increased Parking Control Officer (PCO) and sworn law enforcement officer presence, and / or the addition of one or more bulb-outs, providing more space for pedestrians to pause and take photos without standing in the street (this could also be a temporary solution using paint and planters).

Per the best estimate of revenue, Scenarios 1 and 2 are estimated to generate approximately \$37,000 and \$42,000 in revenue from paid reservations, respectively, during a typical week. Per a maximum plausible estimate (under which all available reservation slots during peak weekend hours are filled), Scenarios 1 and 2 are estimated to generate approximately \$39,000 and \$49,000 in revenue from paid reservations, respectively, during a typical week.

Overall, both scenarios are estimated to modestly decrease overall visitor traffic to the Crooked Street by approximately five percent (each decreasing driving visitors by approximately 40 percent but increasing pedestrian visitors by approximately ten percent).

5. Operational Method & User Interface: Fully-Automated vs. Staffed Operations

Preliminary efforts by SFCTA indicated the potential for a fully-automated solution to implement a pricing and/or reservation system on the Crooked Street. Through the development of the business rules and operational scenarios discussed in this memo, several concerns surfaced that warranted further evaluation of whether a fully-automated solution could be reliably deployed. Therefore, another alternative, which relies on the physical presence of traffic control and enforcement personnel (a staffed solution), was developed to compare with the alternative that relies solely on technology (a fully-automated solution). In this section, the challenges and constraints of each alternative are discussed and the recommended alternative is chosen.

It should be noted that the alternatives presented in this section are preliminary and, as the Concept of Operations is developed, details of the preferred alternative will be further refined and additional components (e.g. technology or staffing related) will be included depending on future evaluations of operational costs and functionality.

Below are short descriptions of each alternative that are evaluated and classifications of users visiting the Crooked Street. This is followed by an assessment of both alternatives through the sequence in which users interact with the system – recognized as pre-arrival, arrival, and post-arrival stages. Both alternatives described below assume that a web-based system is established for users to make and pay for reservations in advance of arriving on site.

User Classifications

The definitions and assumptions of user classifications and user interactions with the reservation system for both alternatives are described below:

- Crooked Street Resident – Individuals who must travel on the Crooked Street to access their home, including residents of the 1000 block of Lombard Street and all of Montclair Terrace. Residents are not required to make a reservation but need to be identifiable to travel on the Crooked Street.
- Guest – A guest (personal, delivery/ service vehicle, etc.) of a Crooked Street resident. Guests are not required to make a reservation but need to be identifiable to travel on the Crooked Street.
- Tourist – A non-San Francisco resident visiting the Crooked Street. Tourists must make a reservation and need to be identifiable to access the Crooked Street.
- San Francisco Resident – A San Francisco resident visiting the Crooked Street. Depending on finalization of business rules, San Francisco residents may be exempt for paying to access the Crooked Street but would still be required to make a reservation.

Alternative 1 – Fully-Automated Solution

A fully-automated solution would rely on technology to detect vehicles using the Crooked Street. This solution would use cameras to capture license plates for all vehicles traveling on the Crooked Street. Vehicles that are detected but are not matched to a reservation would be subject to a violation penalty or fee, with the exception of vehicles designated as being exempt based on business rules. This solution could be used under both the 24/7 Scenario and the 9:00 a.m. to 9:00 p.m. scenarios described in Section 3.

Tourists, residents, and visitors would interact with an automated reservation system as follows:

- Tourists & San Francisco Residents: Similar to other tourist destinations such as Muir Woods, reservations would be made via website in advance of visiting the Crooked Street, with no onsite reservations permitted. San Francisco residents may be permitted to make a no-cost reservation. Cameras would verify observed license plates against reservations upon arrival at the Crooked Street.
- Crooked Street Residents: Crooked Street Resident vehicles, defined as those living on or adjacent to the 1000 and 1100 blocks of Lombard Street, would be pre-registered with the system, with cameras verifying their license plates upon entry to the Crooked Street. An alternative to license plate verification would be via a FasTrak toll tag.

- Guests of residents: Visitor vehicles would be captured by camera, with residents entering license plates of their visitors within a certain number of days before or after their visit on a private system so that no violation penalty or fee would be assessed.

Alternative 2 – Staffed Solution

A staffed solution would rely on personnel, rather than technology, to verify that vehicles using the Crooked Street have made a reservation and to allow designated exempt vehicles to travel without a reservation. With this solution, staff would determine whether users made a reservation by visible observation or by utilizing hand-held devices. Non-exempt users without a reservation would be directed away from the Crooked Street. This solution could only be used under the 9:00 a.m. to 9:00 p.m. scenario described in Section 3, as 24/7 staffing would be costly and inefficient.

Tourists, residents, and visitors would interact with a staffed reservation system as follows:

- Tourists & San Francisco Residents: Similar to other tourist destinations such as Muir Woods, reservations would be made and purchased via website in advance of visiting the Crooked Street, with no onsite reservations permitted. San Francisco residents may be permitted to make a no-cost reservation. On-site staff working with PCOs would verify reservations and direct vehicles to proceed down the Crooked Street. Those without reservations would be directed away from the Crooked Street². Proof of reservation would be demonstrated in the form of a website printout or mobile phone receipt.
- Crooked Street Residents: Crooked Street Resident vehicles would be issued a resident pass, which would be verified by PCO upon entry to the Crooked Street.
- Guests of residents: Visitors would generate a visitor pass via website in advance of their visit or be given a physical pass by the resident who they are visiting, which would be verified by PCO upon entry to the Crooked Street.

Alternative Assessment

Pre-Arrival Stage

The pre-arrival stage involves all the activities that must take place prior to a user arriving at the Crooked Street. This includes the process for making a reservation and the process to register exempt users.

The primary concern in the pre-arrival stage is the ability to reliably register and identify exempt users, including residents, guests, and San Francisco residents.

- In a fully-automated solution, residents would have to register their vehicles online, provide proof of Crooked Street residency, and update their registration any time they change vehicles to avoid being issued a violation penalty or fee. This could be seen as a burden by residents and could require significant administrative involvement and oversight. In addition, residents would be required to register their guests' trip or ask their guests to register their trips themselves. In either scenario, the process of onboarding residents and guests will be cumbersome and, if ignored or forgotten, both user classes are at risk of being issued a violation penalty or fee. Similarly, San Francisco residents would be required to register online and provide proof of residency. The administrative process and oversight to implement exemptions for San Francisco residents will be costly, especially considering that under this exemption there would be no revenue from these reservations to support this additional administrative burden. Therefore, there will need to be considerations for limiting the number of San Francisco resident exemptions allowed per day to combat an oversaturation of exempt trips.

² A detailed traffic management plan will be developed in a future phase of this study.

- In a staffed solution, the administrative burden could be minimized or eliminated by using staff to verify proof of exemption. For example, driver's licenses could be used as a way to verify residency. If visible decals are required, the existing system (residents turning onto the Crooked Street from Hyde show staff a printed resident decal) has already established protocol, which can be modified/optimized in the final concept of operations. Unfortunately, a staffed solution may not provide a significantly better process for handling guest arrivals. It is likely that either an online system to handle guest registration or physical passes that residents must supply to guests in advance of their visits would still be required. As for San Francisco residents, with staff on-site, a driver's license can be used to validate San Francisco residency to either approve or reject the exempt visit.

An additional concern in the pre-arrival stage is handling unknown license plate information.

- In a fully-automated solution, tourists traveling via rental vehicle or taxi/shared vehicle may not have license plate information in advance of their trip. This will require an additional step in the reservation process for tourists who need to update their registration to include license plate information. If not completed within a designated time frame, tourists are at risk of being issued a violation penalty or fee.
- In a staffed solution, license plate data is not required for registration. Instead, tourists will be given a printed or electronic ticket and can show evidence of their reservation to staff on site, including those who are visiting by taxis or other shared vehicles.

Arrival Stage

The arrival stage involves the arrival of vehicles at the Crooked Street. It is assumed that residents and guests of residents will continue to access the Crooked Street by turning right from Hyde. All vehicles that made a reservation will be required to approach the Crooked Street from the 1100 block of Lombard Street, between Larkin and Hyde.

The primary concern in the arrival stage is the ability to effectively and expeditiously manage vehicle arrivals.

- In a fully-automated solution, when visitors arrive at the Crooked Street, license plate cameras would detect, identify, and verify reservation, exemption, or violation status of vehicles entering the system. There is no mechanism to manage those who arrive outside of their reservation window or those who arrive without a reservation at all, expect the threat of issuing a violation penalty or fee. Without the ability to manage when vehicles arrive, the integrity of the reservation system would be compromised. Rule-abiding customers who register, pay, and arrive on time may find that there is a queue on Lombard Street and that it is lengthier than expected. This could introduce difficulties in guaranteeing reservation times, result in the issuance of violation penalties or fees for vehicles that arrive outside of their reservation window, and ultimately compromise the ability to provide a reliable experience for paying customers.
- In a staffed solution, on-site personnel would staff the entrance to the Crooked Street and check confirmations to make sure that tourist vehicles have reservations. Staff can ensure visitors have reservations and are arriving at the correct time. Staff on-site can validate and direct non-reserved visitors away from the Crooked Street, while also managing early and late arrivals with discretion. The presence of staff on-site ultimately provides a safeguard to manage vehicle arrivals, which is a clear advantage over the fully-automated solution. However, the process to manage vehicle arrivals will be lengthier since each vehicle will be approached by staff and documents are exchanged or verified.

An additional concern in the arrival stage is handling service/delivery vehicle visits.

- In a fully-automated solution, all vehicles traveling on the Crooked Street will be captured by license plate cameras. To combat violation penalties or fees for service/delivery vehicles, residents would be required in some way to enter the license plate information for all service types expected at their home. Another solution would be to require service providers to register their trips themselves, through a resident requested portal. In either scenario, documenting every visit is required to ensure the license plate image

review is matched with a recorded visit. This will require significant involvement for residents and/or guests and ultimately additional administration and oversight.

- In a staffed solution, there are opportunities for staff to exercise discretion in the case of delivery/service vehicles and other reoccurring visitors. Establishing criteria and protocol for these types of visits would be necessary and ultimately communicated to staff. The details for this arrangement would need to be discussed further in the concept of operations.

Post-Arrival Stage

The post-arrival stage involves all the activities that must take place after users visit the Crooked Street.

The major concern in the post-arrival stage is the cost associated with violation processing, which could be significant with a fully-automated solution.

- In a fully-automated solution, any vehicle that is not registered through the online portal, or visitor who arrives outside of their reservation window, will be issued a violation penalty or fee. All license plate images captured will be matched to a database of those who made a reservation and those who are exempt. If the license plate is matched to a reservation within the reservation interval (plus a buffer to account for reasonably early or late arrivals), or if the vehicle is on the exempt list, no violation is generated. If no match is made, the license plate is used to issue a violation penalty or fee to the registered owner's address. This process is expensive, including the effort to review images, perform lookups through DMV to obtain addresses, issue violations, adjudicate disputes, and ultimately collect violation revenue. Based on the concerns discussed in the pre-arrival and arrival stages, there is potential for a high volume of violations to occur. For these reasons, outsourcing violation processing to the FasTrak Regional Customer Service Center (RCSC) is assumed to be the only way to manage violations in a cost-effective manner. Based on preliminary discussions with FasTrak, integrating this solution with an accompanying back office function seems feasible. The estimated cost per transaction is approximately \$0.40, plus an additional \$0.88 for vehicles that are issued violations. Factoring in monthly system maintenance fees, Bay Area Toll Authority operations support costs, and credit card processing fees, the estimated monthly cost could be in the range of \$50,000 to \$75,000 per month to process the number of expected transactions.
- In a staffed solution, visitors arriving without a reservation are directed away from the Crooked Street. Violations would be minimized, and only issued to those who disobey staff and PCO instructions and travel down the Crooked Street. These violations would be issued on-site by appropriate enforcement officers depending on enabling legislation.

An additional concern in the post-arrival stage is the risk of fining exempt users.

- In a fully-automated solution, there are circumstances that may result in exempt users being issued a violation penalty or fee, including residents who are not actively managing registration for new vehicles, guests who do not record their trips, and residents/guests who do not properly input their license plate information. This will likely generate additional disputes, require additional administrative services, and may result in a negative experience for the residents of the Crooked Street. There are potential safeguards that can be put in place to combat these errors, but a fully-automated solution will never obtain 100% accuracy.
- In a staffed solution, the risk of erroneously issuing a violation to exempt users is minimized due to the presence of staff that can use a series of protocols to verify and allow exempt users to travel down the Crooked Street.