CONSULTANT SERVICES AGREEMENT BETWEEN THE CITY OF SUNNYVALE AND CITILABS, INC. FOR TRAVEL DEMAND MODEL UPDATE 2018

THIS AGREEMENT, dated _______________________, is by and between the CITY OF SUNNYVALE, a municipal corporation ("CITY"), and CITILABS, INC. (“CONSULTANT").

WHEREAS, CITY desires to secure professional services necessary for travel demand modeling and other services for a project known as Travel Demand Model Update 2018; and

WHEREAS, CONSULTANT represents that it, and its sub-consultants, if any, possess the expertise to provide the required services;

NOW, THEREFORE, THE PARTIES ENTER INTO THIS AGREEMENT.

1. Services by CONSULTANT

CONSULTANT shall provide services in accordance with Exhibit "A" entitled “Scope of Work.” All exhibits referenced in this Agreement are attached hereto and are incorporated herein by reference.

Except as specified in this Agreement, CONSULTANT shall furnish all technical and professional services, including labor, material, equipment, transportation, supervision and expertise to perform all operations necessary and required to satisfactorily complete the services required in this Agreement.

2. Time for Performance

The term of this Agreement shall be one (1) year from the execution date, unless otherwise terminated. CONSULTANT shall deliver the agreed upon services to CITY as specified in Exhibit "A-1". Extensions of time may be granted by the City Manager upon a showing of good cause.

3. Duties of CITY

CITY shall supply any documents or information available to CITY required by CONSULTANT for performance of the services. Any materials provided shall be returned to CITY upon completion of the work.

4. Compensation

CITY agrees to pay CONSULTANT as full compensation for the services rendered pursuant to this Agreement, the amounts set forth in Exhibit “A”. Total compensation shall not exceed Two Hundred Thirty Thousand Five Hundred Ninety Six and No/100 Dollars ($230,596).

CONSULTANT shall submit invoices to CITY no more frequently than monthly for services provided to date. All invoices, including detailed backup, shall be sent to City of Sunnyvale, attention Accounts Payable, P.O. Box 3707, Sunnyvale, CA 94088-3707. Payment shall be made within thirty (30) days upon receipt of an accurate, itemized invoice by CITY's Accounts Payable Unit.

5. Work Product

If CONSULTANT provides to CITY any written reports under this Agreement, CITY is permitted to freely use the information contained in those written reports. If CONSULTANT provides to CITY Cube scripts under this Agreement, CITY may run those Cube scripts using CONSULTANT's Cube software, on the conditions that CITY's software license to use CONSULTANT's Cube software (which is set forth under a different contract) remains in effect.

6. Conflict of Interest

CONSULTANT shall avoid all conflicts of interest, or appearance of conflict, in performing the services and agrees to immediately notify CITY of any facts that may give rise to a conflict of interest. CONSULTANT is aware of the prohibition that no officer of CITY shall have any interest, direct or indirect, in this Agreement or in the proceeds thereof. During the term of this Agreement CONSULTANT shall not accept employment or an obligation which is inconsistent or incompatible with CONSULTANT'S obligations under this Agreement.

7. Confidential Information

Except as otherwise required by law, CONSULTANT shall maintain in confidence and at no time use, except to the extent required to perform its obligations hereunder, any and all proprietary or confidential information of CITY of which CONSULTANT may become aware in the performance of its services.

8. Compliance with Laws

A. CONSULTANT shall not discriminate against, or engage in the harassment of, any City employee or volunteer or any employee of CONSULTANT or applicant for employment because of an individual's race, religion, color, sex, gender identity, sexual orientation (including heterosexuality, homosexuality and bisexuality), ethnic or national origin, ancestry, citizenship status, uniformed service member status, marital status, family relationship, pregnancy, age, cancer or HIV/AIDS-related medical condition, genetic characteristics, and physical or mental disability (whether perceived or actual). This prohibition shall apply to all of CONSULTANT's employment practices and to all of CONSULTANT's activities as a provider of services to the City.

B. CONSULTANT shall comply with all federal, state and city laws, statutes, ordinances, rules and regulations and the orders and decrees of any courts or administrative bodies or tribunals in any manner affecting the performance of the Agreement.

9. Independent Contractor

CONSULTANT is acting as an independent contractor in furnishing the services or materials and performing the work required by this Agreement and is not an agent, servant or employee of CITY. Nothing in this Agreement shall be interpreted or construed as creating or establishing the relationship of employer and employee between CITY and CONSULTANT. CONSULTANT is responsible for paying all required state and federal taxes.

10. Warranty Disclaimer / Consequential Damages / Limitation of Liability

CONSULTANT WARRANTS AND REPRESENTS THAT IT WILL PERFORM THE WORK IN A PROFESSIONAL AND WORKMANLIKE MANNER. EXCEPT AS OTHERWISE EXPRESSLY STATED HEREIN, CONSULTANT MAKES NO REPRESENTATION OR WARRANTY OF ANY KIND WHETHER EXPRESS, IMPLIED (EITHER IN FACT OR BY OPERATION OF LAW), OR STATUTORY, AS TO ANY MATTER WHATSOEVER, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, QUALITY, AND NON-INFRINGEMENT OF THIRD PARTY RIGHTS.

DATA PROVIDED BY CONSULTANT ARE ESTIMATES ONLY, AND WITHOUT LIMITING THE FOREGOING, CONSULTANT DOES NOT WARRANT THAT DATA AND INFORMATION PROVIDED BY CONSULTANT TO CITY WILL BE ACCURATE.

NOTWITHSTANDING ANY PROVISION TO THE CONTRARY, IN NO EVENT SHALL CONSULTANT BE LIABLE TO CITY FOR ANY SPECIAL, INCIDENTAL, INDIRECT, EXEMPLARY, PUNITIVE OR CONSEQUENTIAL LOSSES OR DAMAGES, WHETHER ARISING IN CONTRACT, WARRANTY, TORT (INCLUDING NEGLIGENCE), STRICT LIABILITY OR OTHERWISE.

NOTWITHSTANDING ANY PROVISION TO THE CONTRARY, IN NO EVENT SHALL CONSULTANT’S LIABILITY FOR DAMAGES ARISING OUT OF OR RELATED TO THIS AGREEMENT, WHETHER IN CONTRACT, TORT (INCLUDING NEGLIGENCE) OR UNDER ANY OTHER THEORY OF LIABILITY, IN ANY CIRCUMSTANCES, EXCEED THE LOWER OF THE FEES ACTUALLY PAID TO CONSULTANT AND THE INSURANCE POLICY LIMITS REQUIRED UNDER THIS AGREEMENT.

11. Insurance

CONSULTANT shall take out and maintain during the life of this Agreement policies of insurance as specified in Exhibit "C" attached and incorporated by reference, and shall provide all certificates or endorsements as specified in Exhibit "C."

12. CITY Representative

Lillian Tsang, Principal Transportation Engineer as the City Manager's authorized representative, shall represent CITY in all matters pertaining to the services to be rendered under this Agreement. All requirements of CITY pertaining to the services and materials to be rendered under this Agreement shall be coordinated through the CITY representative.

13. CONSULTANT Representative

Bill Allen, Director of Services shall represent CONSULTANT in all matters pertaining to the services and materials to be rendered under this Agreement; all requirements of CONSULTANT pertaining to the services or materials to be rendered under this Agreement shall be coordinated through the CONSULTANT representative.

14. Notices

All notices required by this Agreement, other than invoices for payment which shall be sent directly to Accounts Payable, shall be in writing, and sent by first class with postage prepaid, or sent by commercial courier, to address below.

Nothing in this provision shall be construed to prohibit communication by more expedient means, such as by email or fax, to accomplish timely communication. Each party may change the address by written notice in accordance with this paragraph. Notices delivered personally shall be deemed communicated as of actual receipt; mailed notices shall be deemed communicated as of three business days after mailing.

To CITY: Jennifer Ng, Assistant Director of Public Works/City Engineer
Department of Public Works
CITY OF SUNNYVALE
P. O. Box 3707
Sunnyvale, CA 94088-3707

To CONSULTANT: Bill Allen, Director of Services
Citilabs, Inc.
2005 N. Street
Sacramento, CA 95811

15. Assignment

Neither party shall assign or sublet any portion of this Agreement without the prior written consent of the other party.

16. Termination

A. If CONSULTANT defaults in the performance of this Agreement, or materially breaches any of its provisions, CITY at its option may terminate this Agreement by giving written notice to CONSULTANT. In the event of such termination, CONSULTANT shall be compensated in proportion to the percentage of satisfactory services performed or materials furnished (in relation to the total which would have been performed or furnished) through the date of receipt of notification from CITY to terminate. CONSULTANT shall present CITY with any work product completed at that point in time.

B. Without limitation to such rights or remedies as CITY shall otherwise have by law, CITY also shall have the right to terminate this Agreement for any reason upon ten (10) days' written notice to CONSULTANT. In the event of such termination, CONSULTANT shall be compensated in proportion to the percentage of services performed or materials furnished (in relation to the total which would have been performed or furnished) through the date of receipt of notification from CITY to terminate. CONSULTANT shall present CITY with any work product completed at that point in time.

C. If CITY fails to pay CONSULTANT, CONSULTANT at its option may terminate this Agreement if the failure is not remedied by CITY within (30) days after written notification of failure to pay.

17. Entire Agreement; Amendment

This writing constitutes the entire agreement between the parties relating to the services to be performed or materials to be furnished hereunder. No modification of this Agreement shall be effective unless and until such modification is evidenced in writing signed by all parties.

18. Governing Law, Jurisdiction and Venue

This Agreement shall be governed by and construed in accordance with the laws of the State of California, excluding its conflict of law principles. Proper venue for legal actions will be exclusively vested in a state court in the County of Santa Clara. The parties agree that subject matter and personal jurisdiction are proper in state court in the County of Santa Clara, and waive all venue objections.

19. Miscellaneous

Time shall be of the essence in this Agreement. Failure on the part of either party to enforce any provision of this Agreement shall not be construed as a waiver of the right to compel enforcement of such provision or any other provision.

IN WITNESS WHEREOF, the parties have executed this Agreement.

ATTEST:

By________________________________
City Clerk

APPROVED AS TO FORM:

By________________________________
City Attorney

CITY OF SUNNYVALE ("CITY")

By________________________________
City Manager

____
("CONSULTANT")

By________________________________

____
Name and Title

By________________________________

____
Name and Title

EXHIBIT A
SCOPE OF WORK

Task 1 Project Work Plan and Management

1.1 Project Management

This task includes the overall organization of the project by the City and the consultant. We will designate a Project Manager who has the authority to make key decisions on our behalf and who is responsible for ensuring the City's satisfaction with this assignment. The Project Manager will hold regular meetings with City staff, either in person or by webinar/phone and will prepare all of this study's documentation, including meeting minutes, presentation materials, and final reporting.

1.2 Kick-Off Meeting

We will work with City staff to organize a kick-off meeting. This will be attended by the key staff from the City, Citilabs, VTA, and other affected agencies. The meeting will introduce the key staff to each other and will describe the technical approach that we propose for this project. We will identify key data items and work with City staff to identify the agencies responsible for providing data. This meeting will also identify some key parameters, as identified in the RFP, such as the zone structure, model inputs, model user interface, validation criteria, model outputs, and optional tasks. Following this meeting, we will prepare a draft methodology memorandum.

1.3 Check-in Meetings

The RFP mentions both bi-weekly meetings and monthly progress reports but it has been our experience that monthly progress meetings are sufficient for projects like this one. A monthly schedule allows for the proper preparation of materials in advance of the meeting and follow-up reporting.

Task 1 Deliverables

- Project kick-off meeting, with agenda and minutes.
- Technical Memo describing the proposed study methodology.

Task 2 Review Existing Data

2.1 Existing Documents

Working with City staff, we will identify the documents needed to support the efficient performance of this project. This includes City documents, such as its General Plan, as well as information that should be available from VTA, MTC, Caltrans, and other agencies. We expect that these documents will describe socioeconomic data files, highway, transit, and bikeway network files, and reports from other models.

2.2 Existing Count Data

We will obtain the Caltrans counts from the PeMS database, as well as the counts that are available from the City's count database, the County, and VTA. This will focus on average weekday counts, hourly counts by direction, classification counts, and turn movement counts. These will be geocoded, adjusted to a common year, posted on the network, and checked for internal consistency. Counts that are inconsistent or are judged to be unreliable will be adjusted or removed. We will also advise the City on whether the existing counts are sufficient for validation or whether additional counts are necessary and if so, where. Based on the count data review, the consultant may identify new locations where counts are needed and will advise City staff, who will arrange for such counts to be conducted under a separate budget.

Task 2 Deliverables

- A memo summarizing the data available, any missing data, and any conflicting information. The memo shall also include a map showing locations where traffic counts are available, and a map showing where additional traffic counts are needed.
- A spreadsheet and link map showing the available counts within the City.

Task 3 Develop Traffic Analysis Zone System

The level of detail of the TAZ system is one of the most critical elements in obtaining traffic assignments that are suitable for supporting detailed analyses such as traffic impact studies. It is very important that the level of TAZ detail be consistent with the level of network detail. The rule of thumb is that there should be 8-12 arcs per zone (an *arc* is a connection between intersections, regardless of how many coded links are involved). If there are too few zones or too few links, the network loading will be uneven and inaccurate. If there are too many zones, that places a larger burden on the user to create the model input files and results in longer model run times. If there are too many links, the assignment run time is increased without commensurate benefit, since many of the links are not loaded. Another rule of thumb is that the highway network should contain one level of roadway <u>below</u> the level that is of greatest concern. So if the City were mainly concerned with Collectors, the network needs to include many Local streets as well, which helps to ensure that the assignments on the Collectors is more accurate.

In order to meet the needs that are described in the RFP, we recommend that the number of TAZes (or *zones*) be increased and that the network detail should be increased as well. The main difficulty with using more zones is that it increases the burden on the user to prepare the model inputs. It can be difficult to find data that permits the reasonably accurate allocation of land use activity (households and jobs) at the level of Census block or smaller. We will work with City staff to identify such data. Population by Census block is one possibility, but there are fewer than 300 such blocks in the City and so that will not be sufficiently detailed. A more likely source is the City's land parcel database (such as is used for taxation). This task will be conducted simultaneously with Task 5 (roadway network) so as to ensure that the zone system and network are compatible. Once the new system is established, we will create a shape file in Esri format that identifies the new TAZ boundaries.

The Sunnyvale model currently has 2,828 zones of which only 173 are within the City. This system appears to have been designed for the sake of consistency with the VTA zone system. Although that does have its benefits, we believe that significantly more zones and more network detail must be added within the City, in order to support turning movement accuracy and sufficient assignment accuracy for TIA purposes, as the RFP discusses. In the neighboring cities (Mountain View, Santa Clara, Cupertino), the existing VTA zones probably provide sufficient detail. In order to keep the number of zones low enough so that the model runs within reasonable time limits, this may also require the aggregation of some zones in areas that are distant from the City, such as Marin or Solano Counties. Another way of reducing run time is to use a disaggregate model structure, in which the run time is related to the number of trips, not the number of zones (see more on that below).

Task 3 Deliverables

- Maps/plots showing the proposed TAZ splits.

Task 4 Review Existing Data

4.1 Existing Land Use Inventory

The key question is what variables should be included in the land use file. A commonly used list is shown below. As with the zone size issue, the key tradeoff is that using more variables typically makes the model more accurate, but having fewer variables makes the model easier to use. Our experience is that the list below represents a reasonable compromise between these objectives. This will be discussed with City staff and agreed upon as early as possible in the project.

Table 1
Recommended Land Use Variables

Variable	Description
Households	Occupied dwelling unit; basic unit of trip generation
HH Population	People living in HHs; used to estimate HHs by size
GQ Population	People living in group quarters (dorms, barracks, nursing homes, prisons)
Average HH Income	Used to estimate HHs by income group and vehicle ownership
Retail jobs	Determines Shop attractions
Office jobs	Helps identify major business districts
Industrial jobs	Determines Truck attractions
Service jobs	Determines personal business attractions
Other jobs	Includes jobs not classified above
K-12 Enrollment	Determines School attractions
Univ. Enrollment	Determines University attractions

Census data and City land parcel data are usually sufficient to identify the population-related data items. School enrollment is usually available from the school authorities and each major university. The consultant understands that the City has some land use data but is not fully confident of its accuracy and that this study needs to address that issue. Census data typically has good income data. The major challenge is usually in identifying employment by type at its actual location. Census Longitudinal Employer-Household Dynamics (LEHD) data can be helpful with that task, as well as state employment records, and there are numerous commercial databases that provide this information at a cost. The consultant has contacted several private companies to determine the availability of suitable data. As of this writing, we are still awaiting their responses, but we recommend establishing a budget of $7,500 for such data as a contingency and have included this amount in the project budget. Given the concerns expressed by City staff over land use accuracy, this seems like a prudent step.

Another issue is what to use as the model calibration base year. Preferably, all of the data used in model development should reflect the same year, but this rarely occurs in practice. Typically, the availability of the most recent traffic count data is the controlling factor and it is likely that this will be for 2017. We will discuss this with City staff and reach an agreement on the base year. The City's land use data file will be updated to the base year using the agreed upon variables.

4.2 Approved/Pending Land Use

City staff will provide us with a list of projects that are in the "development pipeline". We will work with City staff to identify the location, size, and nature of each development – type of housing or expected type of employment, so that this information can be transformed into inputs that are suitable for the model. This information will be used to establish a short-range forecast of City land use, for a horizon year that is selected by City staff.

4.3 Buildout Land Use

Estimating the level of buildout in each zone requires the following: 1) the land area that is available for development, 2) the current zoning category, and 3) information on the potential for redevelopment or rezoning. The first two items are straightforward, but the third requires significant input from City staff. It may be possible to estimate the potential for redevelopment based on some measure of the condition of the current building stock, such as the following:

- HH income: low income areas could be subject to gentrification
- Building age: older buildings are more likely to be reused or razed
- Building condition: buildings that are not well-maintained are more likely to be razed

With the help of City staff, we will assign a "redevelopment index" to each TAZ to indicate the relative potential for changes to occur in the level of development in the TAZ. This can be used to estimate the buildout potential for the City.

At the option of City staff, instead of a true "buildout" analysis, this task could be modified to reflect the level of development that is described by the current City Comprehensive Plan.

4.4 Review Zones for Consistency

We will review the compatibility of the new zone system with other zone systems (e.g., Census, VTA), which may suggest additional changes. We will also double-check the zone compatibility with the roadway network (Task 5) to ensure consistency. The final zone system will include three levels of detail: increased detail within the City, VTA-level detail in the adjacent cities, major employment areas, and areas near major transit stations, and aggregations of VTA zones in areas that are more distant from the City. We will also include Cube scripts that facilitate the conversion of data from other agencies (VTA, MTC) to the new zone system.

4.5 Land Use for Neighboring Cities

The principal source of land use data outside the City will be the information compiled by VTA. We will also contact the immediate adjacent cities of Mountain View, Santa Clara, and Cupertino to request land use data, so as to ensure that the model includes their most recent land use data and forecasts.

4.6 School Data (Optional)

As Table 1 indicates, we believe that school enrollment is an essential element of zonal data and we propose to identify and geocode those schools that are used by Sunnyvale residents (grades K-12). We will contact these schools or the respective school boards to obtain data on enrollment. This task also includes the major colleges and universities in the region, especially those that have significant levels of students commuting from Sunnyvale. For clarification: the base model will include both School and University trip purposes. In this optional task, we would include specific school district boundaries and other such data, so as to improve the accuracy of the School and University destination choice models.

Task 4 Deliverables

- Base year (Existing) land use inventory by TAZ.
- List of known development by TAZ and by status: Approved/Buildout/Year of occupancy.
- Maps/plots showing the proposed TAZ zone splits/additions.
- Maps/plots showing the type of land use and the amount of land use by TAZ.
- Maps/plots showing the growth of land use by type by TAZ.
- Updated TAZ layer in GIS shapefile format.
- GIS shapefile to include existing and future school boundary. (Optional Task)

Task 5 Develop Roadway Network

5.1 Existing Roadway Network

We will review the existing City model’s roadway network. As noted above, this is not sufficiently detailed to meet all of the needs outlined in the RFP. We will also examine other sources of roadway information, such as HERE and OpenStreetMaps. We expect that the new network will include all Freeways, Arterials, and Collectors within the City and a reasonable percentage of the Local roads, including some neighborhood streets. This will include all signalized intersections in the City. We anticipate that the key network attributes, such as facility type and number of lanes, will be available from existing sources.

As noted above, the network will be developed so as to maintain consistency with the zone system. If additional network detail is needed in a certain area, we will ensure that the zones in that area are sized appropriately (and vice-versa). The highway network will also be developed so as to be consistent with the transit network.

The likely network attributes will include those shown in Table 2. Some of these are user-coded, while others are computed by the model. It is our experience that these variables will allow the user to analyze a wide variety of highway related strategies.

Table 2
Proposed Network Attributes

Variable	Notes
User-Coded	
Length	Actual link distance
Road Name	
Speed Limit	Posted limit
Facility Type	Code describing the physical attributes of the link, typically using 8-12 codes
Usage Restrictions*	Code to indicate HOV restrictions, truck restrictions, etc.
Speed Mod	User coded override to the look-up table speed
Capacity Mod	User coded override to the look-up table capacity
Functional Class	Code to indicate ownership or administrative control of the road
Toll	Toll or toll class code (future use)
Lanes*	Number of mid-block lanes
Count ID	Code indicating the count station
Computed by Model	
Area Type	Code to indicate range of development density
Zone	TAZ for this link
Free Speed	Free-flow speed from look-up table
Capacity	Hourly capacity per lane from look-up table
Total Capacity	Hourly capacity per lane * number of lanes

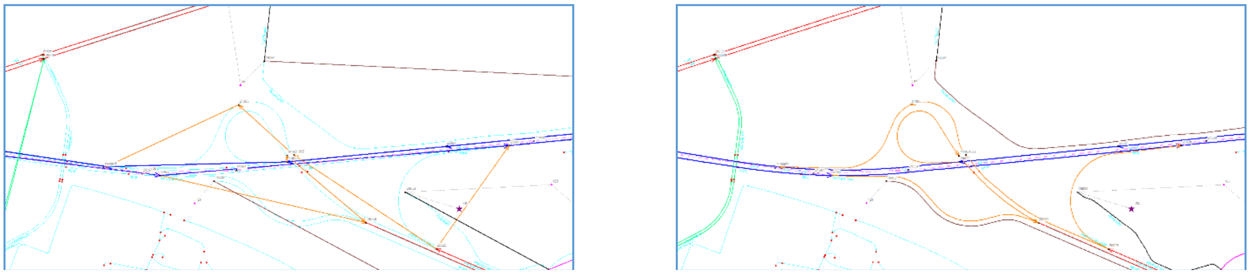
Notes:
* These could vary by time period.

We also suggest that the network be developed using True Shape Display (see Figure 2). This is a Cube feature that allows the coded network to be shown as it exists on the ground, with the proper alignment of curved roadways. Although it can take some time to initially set this up, it makes network editing easier and enables the output network to exactly overlay the City's other GIS files.

Figure 2
True Shape Display

Without TSD

With TSD



We will examine the use of intersection (junction) modelling for this network. In a built-up area, most of the traffic delay occurs at intersections. Thus, it is important to model intersection conditions more accurately. Cube can model the delay associated with each turning movement with great detail and more accuracy than is typically applied. Cube version 6.4 supports HCM 2010 methods for modeling of All-Way stop controlled, Two-Way stop controlled, and Roundabout intersections. This also allows the model to be more sensitive to potential intersection improvements, such as added turn lanes, turn bay length, channelization, turn restrictions, parking restrictions, and signal timing. Using intersection modelling increases the complexity of network coding, but it allows the model to respond to a larger range of specific traffic engineering strategies. We have also developed a simpler approach that we call a *Control Device Model*. This permits the estimation of the approximate added delay at intersections, without the high level of coding and input data required by standard junction modelling. We will review the options with City staff to find the approach that provides the best tradeoff between accuracy and user effort.

5.2 Future Roadway Network

The challenge of coding a future roadway network lies mainly in establishing a list of potential improvements and then deciding which of those improvements are likely to be made for any particular forecast year. This can take many forms. One approach is to code an *Existing* + *Committed* (E+C) network, which reflects only those improvements that are in the pipeline for construction. Another approach includes those projects that are on the state and local Transportation Improvement Plans (TIP), which usually reflects a 5-6 year horizon. In the longer term, many jurisdictions code a *Constrained Long-Range Plan*. This is a 20-30 year horizon but includes only those projects for which funding can readily be identified and reasonably assumed to occur. Another option is to code an *aspirational* plan, which includes a larger group of projects, regardless of whether their funding is assured. Another issue in many areas is that if the City wants to require private developers to make road improvements, those improvements must be included in a future network, even if the development that is related to the improvement is speculative. It should also be clear that in order to code <u>any</u> road improvement, certain aspects of the project must be known, such as facility type, number of lanes, and intersection treatment.

We will work with City, County, MPO, and Caltrans staff to identify those improvements that should be included for the future year and will code them in the network. We will create a table summarizing all network changes. We will also create scripts and procedures to perform a variety of network checking and reporting tasks, such as automated comparison of two networks. We will review work by others to develop a "network database" that can be used to help network coding for intermediate years. It is also possible that creative use of the Cube LOG function can help with this task.

Task 5 Deliverables

- Lists of transportation improvements**.**
- Maps/plots showing existing roadway network, with area type, facility type, number of lanes, speed, etc.
- Maps/plots showing future roadway network, with area type, facility type, number of lanes, speed, etc.
- Maps/plots showing the improvements in the roadway network for roads that are new, removed, widened, narrowed, etc.
- Documents containing rationale for improvement assumptions.
- Turn penalty or turn prohibitor assumptions for Base Year and Future Year.

Task 6 Develop Transit Network

6.1 Existing Transit Network

Since VTA handles the transit network coding for the region, we will request their network data. We will review the current transit network and check to be sure that it is coded accurately, reflecting the base year conditions (probably 2017 or 2018). We do not anticipate the need to make a lot of changes to the current coding methodology. We will review the existing frequencies, service levels by time period, fares, transfer policies and locations, and route run times. We will also review the coding protocol used at major transit stations, to ensure that it represents a good tradeoff between detail and user effort.

Access coding is a major part of transit network analysis. We will check the walk links to be sure that access is available in the coded network where it exists on the ground. Using smaller zones (as described above) will also improve the accuracy of the transit access coding. For drive-access, we propose an innovative approach that enhances accuracy and reduces the input requirements. Instead of coding specific drive-access links, we will use the highway network to determine home-PnR lot access and travel time. This involves a *matrix convolution* process that allows the model to consider multiple drive-park-ride paths from each zone and picks the one with the lowest overall equivalent impedance. This can be done quickly with a Voyager Matrix step. It not only avoids the need to identify drive-access "sheds" or to code drive-access connectors, it also allows the drive-access leg of the trip to be input to the vehicle trip table and included in traffic assignment.
Another element of transit coding is to ensure consistency between the network and the mode choice model. All transit sub-modes should be represented and allowance should be made for modes that do not exist today but which might be considered in the future. In addition, we will examine the new trend in the US towards the international approach in this area. Most US models use a complex multi-level nested mode choice model and a simple transit assignment process. Most European and Australian models use a simpler

mode choice model (auto vs. transit) and a more sophisticated transit assignment step, because this is said to provide greater accuracy and sensitivity. In fact, MTC was one of the first US agencies to examine this alternative approach. We will discuss this idea with the City and MTC, to learn about MTC's experience with it and to see whether it would benefit the new model.

6.2 Future Transit Network

Most of the same concerns expressed about the future highway network also apply to the future transit network. This information will also be obtained from VTA. *Coding* is simple. The hard part is deciding which improvements should be reflected in the future year inputs. Another issue with transit networks involves precision. Some planners believe that it is necessary to reflect every single attribute of new service, in great detail. Our experience is that this often represents false precision. It is helpful to remember that this is not intended to be an *operational* model. It is a *strategic* model, used for planning purposes. Keeping that in mind will help prevent future network coding from becoming unnecessarily tedious.

Task 6 Deliverables

- Lists of transit improvements, such as change in frequency and headway.
- Maps/plots showing existing transit network, including stops.
- Maps/plots showing future transit network, including stops.
- Documents describing future transit improvement assumptions.

Task 7 Trip Generation (HH Synthesis, Tour Frequency)

As noted above, we propose to develop a new simplified tour-based model. This is an improvement upon the conventional four-step structure. The steps are different, but easily recognizable. These new steps are described in the next several sections.

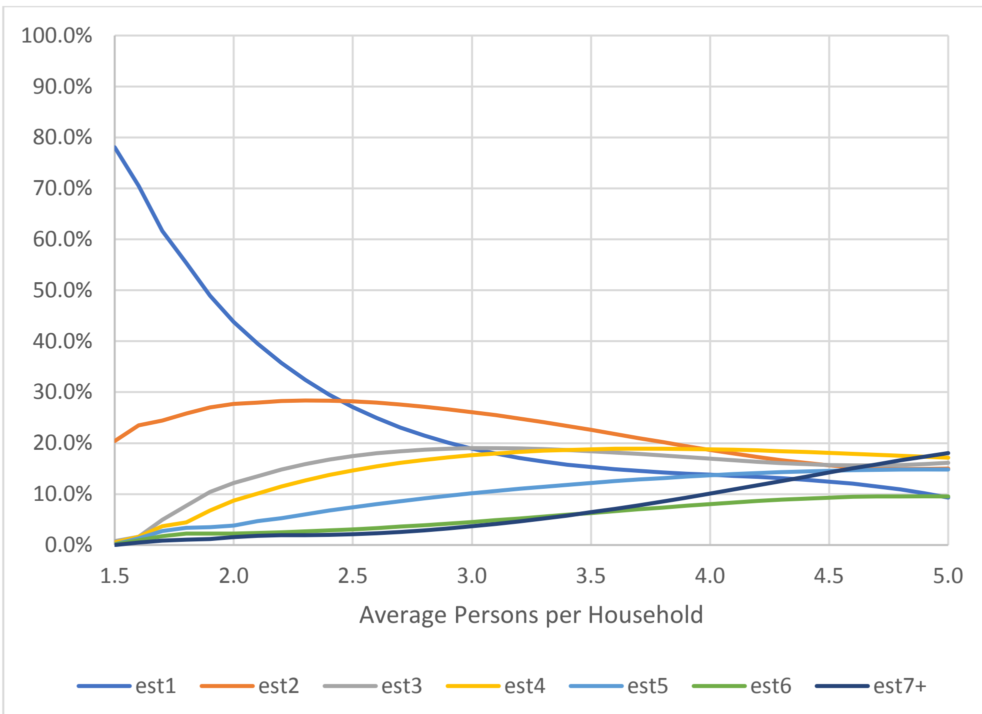
7.1 HH Synthesis

All discrete models start with a step that estimates basic demographic characteristics at the zone level. Our STM uses the **household** as the main demographic unit, rather than the person, which is more common for ABMs. We prefer using the household, since it is the unit for which most travel decisions are made. In addition, it is much simpler to estimate only household attributes, instead of using a population synthesis approach, which tries to estimate both household and person attributes simultaneously, which is a major challenge.

In fact, the Household Synthesis (HS) process that we have developed is actually quite similar to the procedures used in most recent four-step models. Average HH size and average zonal income are used to create a joint *size/income* table for each zone. Averages are converted to discrete distributions using curves such as shown in Figure 3.

We then use Census data to create a third dimension, representing the number of *workers* (0 – 3+) and a fourth dimension, representing the HH *life cycle*. These use look-up tables based on Census PUMS data. This is an attribute that we adapted from prior research. We use three categories: 1) if there are any retired people, 2) if there are no retired people but there are any children, 3) no retired people or children. This is a relatively simple stratification, but we have found that it is very helpful in identifying trip rates for different HHs. Since the major demographic issue for the next 20 years is the aging of the population, this is an especially important attribute to include in a travel model. We have also done some research into using an age-based cohort survival methodology for forecasting this variable. This shows promise, but we have not yet implemented it in practice. In a recent application, we also added a logit vehicle choice model to this process.

Figure 3
Sample Household Size Model



Other potential attributes could include more specific estimation of persons by age, which would account for the different travel potential by children in different age groups. One could also hypothesize a wide variety of specific attributes such as availability of free parking, transit pass ownership, availability of employer-based commuting incentives, adoption rates of autonomous vehicles, etc.

We believe that our household-based approach provides a good tradeoff of familiarity, simplicity, and short run time vs. accuracy. It is similar to currently used methods, with the main difference being that the output is a list of HHs by zone with specific attributes for each HH. For Cape Town, South Africa (1.9 million HH in the province), this process runs in 70 seconds as a single Cube script. A similar population-based process such as PopSyn can take up to 6 hours. We suspect that the additional accuracy of such a process (if any) does not outweigh such a difference in run time.

7.2 Tour Frequency

Once the HH attributes are known, the next step is to estimate the number of round-trip tours per HH by purpose. We typically use conventional purposes such as Work (HBW), School (SCH), University (HBU), Shop (HBS), Other (HBO, and At-Work (ATW), but can modify this as agreed upon by City staff. The Tour Frequency (TF) model is a straightforward multinomial logit model for each purpose, combined with Monte Carlo simulation to identify a specific number of tours. The output is the number of tours by purpose. The logit model is used for the vast majority of tours and a fixed set of fractions is used for the low-percentage tours. Table 3 shows an example from Charlotte, NC for HBW tours.

Table 3
Tour Frequency Example

Tours	Percentage	How Modeled
0	51.9%	Logit
1	29.2	Logit
2	15.0	Logit
3	3.1	Fixed
4	0.7	Fixed
5	0.1	Fixed

So the HBW model consists of 2 utility equations. For zero tours, the utility is defined as zero by convention. One equation is used for making one tour and another equation is used for 2+ tours. If the model initially selects the 2+ option, a set of fractions is used in a separate Monte Carlo process to identify a specific number of tours: 2, 3, 4, or 5. This method avoids the difficulty of trying to fit a logit model to an option that has very few observations. The utility equations consist mostly of demographic attributes, but zonal geographic variables such as area type and accessibility also play a role. The discrete model structure actually makes it simpler to incorporate adjustments for transit-oriented developments, mixed-use developments, and other strategies that discourage single-occupant auto usage.

Also, the hierarchy of purposes is significant. We use the following, in order of decreasing priority: School, University, Work, Shop, Other, At-Work, and this is the order of model application. HBW tours are influenced by whether any SCH tours have been estimated. HBS tours are influenced by HBW and SCH tours. HBO tours are influenced by all of the less significant purposes. The coefficients on the earlier purposes are all negative, which makes sense. If the HH makes an HBW tour, there is an opportunity for shopping or personal business on an intermediate stop, so that there is less need for a specific HBS or HBO tour. Also, if higher priority tours are made, this leaves less time to make lower priority tours.

All tours are assumed to be round-trip tours by all people by all modes that begin and end at a household, except for the At-Work purpose. Here, the basic demographic unit is the *worker* and all travel is assumed to begin and end at the worker's usual workplace. Thus, the ATW tour frequency model can't be applied until after the next step, so that the workplace is known.

An adaptation that may be necessary for the Sunnyvale area is the inclusion of tours made by group quarters residents. This includes dormitories, nursing homes, prisons, and military barracks. These people are not included in the Household Synthesis model, so it might be necessary to create a "GQ Synthesis" process to estimate their characteristics, which would allow for their inclusion in the TF model.

This process is very efficient and quick. For Cape Town (about 4 million tours), it runs in about 3 minutes, as a set of Cube scripts. The TF model is typically calibrated by using survey data. The Caltrans statewide survey will be examined to see if it is a suitable candidate for this purpose. The NHTS is another potential source, although its sample size is often too low.

Task 7 Deliverables

- Technical Memo describing the Household Synthesis and Tour Frequency models.

Task 8 Trip Distribution (Destination Choice)

8.1 Destination Choice

The next step is to estimate the main destination of each tour. For HBW, SCH, and HBU this is obviously the main workplace or school location. For the other purposes, it is typically defined as the location of greatest duration. That is, the place where you spent the longest time is assumed to represent the prime motivation for the tour. The activity at that location then defines whether the tour is HBS or HBO.

The multinomial logit structure is used for Destination Choice (DC). This is becoming increasingly popular, even with trip-based models, since it can account for more influences than the gravity model. For example, this allows the explicit consideration of transit service, HOV lanes, and toll roads on destination choice. In theory, this should reduce the need for K factors or other such geographic adjustments. Since income, vehicle ownership, and other key HH attributes are available in this step, it is possible to estimate coefficients on auto and transit time that demonstrate their true influence on destination choice.

One of the key issues for the DC model is the estimation technique. In truth, each tour typically has *thousands* of possible destination zones. A few can be easily screened out: no HBW tours to a zone that has no employment, no SCH tours to a zone with no school enrollment, etc. But no logit estimation software can handle thousands of possible choices. In practice, a small subset (e.g., 20) of the possible destinations is used in model estimation.

Another important issue for DC is the type of attraction constraint. The conventional gravity model is doubly-constrained, meaning that it attempts to match a set of zonal attractions that are estimated by the attraction model. In contract, almost all discrete destination choice models are singly-constrained, meaning that they do not try to match an estimated set of zonal attraction targets. The proponents of this approach argue that since the typical logit destination choice model already contains a zonal *size variable* that is defined by the number of jobs or other attraction indices, that it is unnecessary to include an additional constraint. They also argue that without such constraint, the model can do a better job of reflecting the impact of accessibility on destination choice, which some modelers believe is an important influence. It is also possible that another, practical issue is at hand: including an attraction constraint in a discrete choice model is either mathematically difficult or very time-consuming. Gravity models achieve this constraint by an iterative process but the time required to run a typical destination choice model effectively prohibits an iterative technique as an option.

We have created a new way of implementing an attraction constraint: as each tour is processed, a destination zone is chosen. One attraction is then subtracted from that zone's list and an adjustment is calculated on the utility for that zone, for the next tour. This not only produces improved results, but also facilitates the use of attraction adjustments that reflect the effects of urban form, increased density, and mixed use on a zone's attractiveness.

Our approach to Destination Choice includes the explicit estimation of which tours will remain within the City (I/I) and which will be external (I/X). This is important, since many tours are expected to be external (either I/X or X/I).

Typically, the DC model is calibrated by checking the model's trip length frequency distributions, the percentages of intrazonal trips, and the district-district trip tables, by purpose, against survey or Census data. In general, Destination Choice is one of the most critical model steps and we recommend that various options be examined during the Investigation phase, to ensure that these results can be as accurate as possible, preferably without the need for any geographic bias factors.

8.2 School Destination Choice (optional)

In many jurisdictions, the school (grades K-12) that one attends is dictated by one's home location (for public school students) and not by typical destination choice considerations. If City staff desire, we can implement a different DC process for school trips that adheres to the existing school board regulations regarding school assignment.

Task 8 Deliverables

- Technical Memo describing the Destination Choice model.

Task 9 Mode Choice, Intermediate Stops, Time of Day

9.1 Mode Choice

This component is actually very similar to its counterpart in a four-step model. The major difference is the addition of a Monte Carlo process so that instead of calculating modal shares by O/D pair and market categories, a specific mode is selected for each tour. Some additional considerations:

- Non-Motorized Travel: Many travel models estimate non-motorized trips in the trip generation phase. This has some advantages, as some modelers have found that including walk/bike trips in trip distribution (destination choice) makes that process more complicated. However, it also prevents the explicit consideration of any tradeoff between non-motorized and other travel modes. Thus, some newer travel models estimate non-motorized travel within the mode choice process and we recommend that this be considered here.

- HH Attributes: The use of a discrete modeling process allows the mode choice model to consider several HH attributes that cannot be included in an aggregate model. Of specific interest is the ability to reflect both income and vehicle ownership, HH life cycle, or the interactions of different HH variables, such as vehicle ownership and workers (the *auto sufficiency* variable that some modelers favor). We also believe that including such variables may help avoid the use of district-level market segmentation factors. This capability comes with a caution however: if mode choice can now be made more sensitive to HH attributes, this may be more accurate, but it also makes that choice less sensitive to system characteristics. Since a primary use of a travel demand model is to evaluate changes in transport system characteristics, this could be unpopular with model users who would expect (and prefer) to see a model that is *more* sensitive to system changes.

- Taxi/TNC: With the advent of Uber, Lyft, and similar transportation network companies and car sharing services, this seems like a good time to incorporate this mode directly into the mode choice model. We suspect that Taxi and TNC can be effectively treated as one mode since their service characteristics are so similar.

- Auto Occupancy: As with nearly all current mode choice models, this model not only splits travel by auto, transit, taxi/TNC, and non-motorized modes, but within the auto mode, travel is further split by vehicle occupancy. This makes it possible to assign trips separately to HOV facilities. This split is based largely on purpose, vehicles and workers in the HH, trip length, time savings on the HOV facility, parking cost, and workplace density.

- External Travel: This model must specifically consider all markets for public transport services, including the markets for longer trips, such as to San Francisco and other distant places that are served by public transport.

- "Flattened" Mode Choice: We will examine both the traditional US method (complex nested model) and the newer structure that is being examined by MTC and a few other agencies ("flattened" model with fewer choices). In fact, our staff recently wrote a technical paper on this subject that we presented at the Australian Institute of Traffic Planning and Management (Australia's TRB) most recent annual meeting. We believe that a simpler mode choice process combined with more sophisticated transit assignment (using Cube's new *crowding* feature) could produce better estimates of trips by sub-modes.

- FTA Coefficients: In the US, it is fairly common for a home interview survey to capture so few transit trips that it is not feasible to estimate statistically reliable and logically reasonable transit service coefficients for mode choice. To address this issue, the Federal Transit Administration has suggested a set of logit coefficients and coefficient relationships that they believe provide reasonable sensitivity across a variety of system changes. FTA strongly prefers the use of such coefficients for studies of system changes that may be subject to Federal funding. In our experience, it is worthwhile and cost-effective to seriously consider the use of such coefficients.

- On-Board Survey: One way to check the FTA transit service coefficients is through an on-board transit survey. We use the most recent on-board survey to create the frequency distribution of observed trips by walk time, wait time, transfer time, ride time, and fare. These can be directly compared to similar distributions that are estimated by the model. Such comparison readily identifies any biases in the system coefficients and suggests modifications to reduce such biases.

- Drive-Transit Trips: The current "best practice" in travel modeling is to include the auto component of drive-transit trips in the vehicle trip table so that they can be included in the vehicle assignment and we propose to include this feature. We have developed a process in Cube that uses the highway network to model drive access to transit (sometimes called *matrix convolution*) and have combined this with PnR models that examine a wide range of drive-transit options and allocate trips to different paths. A helpful feature of this process is that it avoids the use of drive-access "sheds" and the need for manual coding of drive-access links, thus greatly reducing the input data burden on the user.

- Employer-Based Incentives: The Silicon Valley has a high share of office workers and people who work for large employers. It is easier for such employers to provide their workers with incentives to avoid driving alone to work. This has also become an issue in recent years as it concerns attracting and retaining employees. Our staff have done a lot of research into employer trip reduction programs and their effect on commuting mode share, including major programs such as Regulation XV in Southern California. It is possible to incorporate the effects of these ETR programs into the mode choice model. However, doing so will increase the input data requirements, and thus the burden on the user, so this must be balanced against the benefits that this feature would bring to the model.

As noted above, mode choice calibration is difficult. The conventional approach of estimating a nested logit model directly from a home interview survey is complicated by the relatively low number of observations. In addition, some of the modes that should be included, such as TNCs, are so new that they might not show up in any survey data, meaning that there is little or no observed data on them. We propose to use a combination of asserted and transferred coefficients, combined with detailed checks of the results against available survey data and rider counts, to create the most reasonable picture of mode choice that is possible. Target totals of observed riders by sub-mode and route will be established, as the available data permits.

9.2 Intermediate Stops

This process truly sets this model apart from a conventional model. At this point in the model chain, we know the origin, destination, and mode of the tour and we need to now identify the number and locations of intermediate stops. This is an area in which the straightforward tour-based model actually overcomes one of the limitations of ABM. ABM models group travel into a fixed set of patterns, such as origin-stop-destination-origin or origin-stop-stop-destination-stop-origin. However, STM considers **all possible combinations** of stops for each half-tour, up to whatever maximum limit is identified in a survey (2 – 7 in Charlotte, depending on purpose).

The model is a straightforward multinomial logit, using separate models by trip purpose and half-tour (home to destination and destination to home). The choices are from zero to the maximum number of stops for each purpose/direction. The principal variables are those describing the land use around the tour origin and destination zones, and the tour length, and HH attributes play a minor role. In Charlotte, the key influences are:

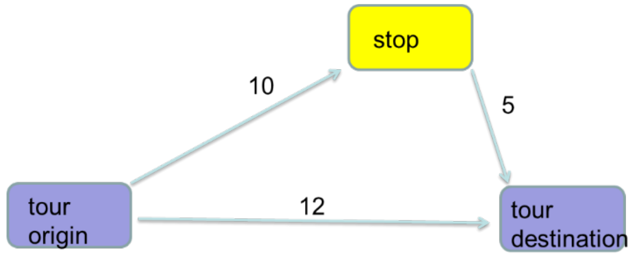
- Number of retail employees within 3 mi of the home zone.
- Longer tours have more stops.
- Intrazonal tours have fewer stops.
- If the traveler made any stops on the first half-tour, he is more likely to make stops on the second half-tour. Because the half-tour models are estimated and applied in sequence, the second half-tour model "knows" how many stops were estimated for the first half-tour.
- Other influential variables: home zone area type, destination zone area type, total number of tours in the HH, HH income.

Conceptually, this model is very similar to the Tour Frequency model. It is estimated and applied in similar fashion. This similarity helps make our STM easier to understand.

Once the number of stops by half-tour is known, the next step is to estimate the locations (zones) of those stops. This process uses another set of multinomial logit models, very similar to the Destination Choice model in that it is selecting a specific zone for each intermediate stop. This particular model highlights one of the key advantages of the discrete tour-based model mentioned above: the improved ability to identify the locations of intermediate stops (NHB locations) because the tour origin and destination are known. An interesting element of this model is that it does not identify the *purpose* of each stop. Our analysis has shown that nearly all intermediate stops are made for either shopping or personal business and that accounting for the specific motivation for the stop does not improve model accuracy.

The key variable in the Stop Location process is *detour time*. This is the time that a traveler has to go out of his way to get to an intermediate stop. In the example in Figure 4 the detour time is 3 minutes (10 + 5 – 12). Other key variables include zonal area type, accessibility, and household income group.

Figure 4
Detour Time



In addition, some of our SL models are further stratified by the stop number. That is, in a multi-stop tour, the location of stop 1 is highly influenced by the tour origin zone. In turn, the location of stop 2 is highly influenced by the locations of stop 1 and the tour destination zone. Making the stop zones conditional on prior stop zones as well as the main origin and destination zones is a major step forward. In Charlotte, this turned out to be more important than the purpose of the tour itself.

Another key issue in this model is the search radius. In most cases, the intermediate stop zones are located in the general vicinity of the tour origin and destination zones. But sometimes, people make some strange-looking tours, in which some stops are quite distant from the origin-destination "axis". A balancing act is required here between accuracy and run time. In order to obtain accurate stop locations that match the patterns observed in the survey, you need to examine a fairly large number of candidate zones, some of which can be quite distant from the tour O/D locations. But if you allow the model to look all over the region for candidate stop zones for each tour, it makes the model run time unacceptable

9.3 Time of Day

One of the simplifications of STM is that we start with conventional time periods: AM peak, midday, PM peak, night. For strategic model applications, this is sufficient. For more detailed applications, such as site traffic analysis, an additional component is needed to split vehicle traffic into smaller time increments. One approach to this involves developing finer time splits based on geography, which captures the effect of the *rolling peak*. This is common in suburban jurisdictions, which often have an early peak associated with long-distance commuters and another peak caused by local commuters.

An important feature that this model should consider is sensitivity to congestion. It is well-known that small changes in departure time can have significant impacts on overall travel time. Evidence exists of people changing their departure time in response to congestion, *within certain limits*. It's one thing to leave home for work at 8:45 instead of 8:30, but very few people are willing or able to make *major* changes, such as leaving at 5:30 instead of 8:30. Our staff have considerable experience in examining congestion and ascertaining its effects on departure time. The availability of flextime among large private employers is also a consideration here.

This model is usually calibrated from survey data but must be carefully validated by comparing traffic assignments by period to hourly count data.

Task 9 Deliverables

- Technical Memo(s) describing the Mode Choice, Intermediate Stop, and Time of Day models.

Task 10 Traffic Assignment

10.1 Trip Accumulation

At this stage of the model, the output consists of a complete set of tour records, which contain all of the information about each tour: destination, mode/occupancy, stops, and time period. The last step before assignment is to convert these records into conventional trip tables. These are in O/D format and are stratified by period and occupancy in preparation for assignment.

10.2 Regional Assignment

We will develop a procedure to perform regional traffic assignment by four time periods, with a final step to sum the results to average weekday volumes. Hourly volumes will be computed as a fixed percentage of the period volumes. This will start with the existing model's assignment methodology, which we will review and revise in order to be more efficient and to take advantage of the latest Cube developments. We would also strongly encourage the City to purchase and apply Cube Cluster, as it results in significant time savings when used with a computer with multiple processors. Some additional assignment considerations:

- VDFs: The volume delay functions can be evaluated by comparing the model output speeds to observed speed data from services such as INRIX or HERE. Also, we will compare the volume/count ratio across various values of volume/capacity ratio – this will clearly indicate any bias in the VDF curves.

- Tolls/Pricing/Managed Lanes: There are many different ways to model the effect of tolls, including different kinds of roadway pricing schemes, managed lanes, high-occupancy toll (HOT) lanes, etc. A simple method is to convert the link cost to equivalent time. A more accurate method is to implement a logit toll diversion model within the assignment step, which is sensitive to trip purpose and traveller income. These methods have very different implications for model run time and we would work with City staff to find an approach that represents a suitable trade-off.

- Link Restrictions: It is possible to set up an assignment process that can handle a wide variety of roadway schemes, such as HOV/HOT lanes, truck restrictions, reversible roadways, pricing, and regulatory strategies that vary by period. However, handling such schemes complicates the network coding and makes the assignment run longer, so we would discuss these ideas with City staff before implementing them.

- Stochastic: In a congested, grid-like network like much of Sunnyvale, we have discovered that conventional assignment techniques are often unsuitable. We have recently found improved performance from the *stochastic* assignment method.

Whereas the standard equilibrium method identifies different paths based only on congestion, stochastic finds multiple paths for all O/D pairs. This produces more logical and stable results that respond more sensibly to network changes, but it does take slightly longer to run, so it must be applied with caution.

10.3 Peak Spreading (Optional)

Our research into trip departure time over the years has indicated that the share of daily traffic travelling in the peak periods (6 –10 am, 3:30 – 7:30 pm) has remained relatively stable over time. However, *within* those peak periods, there is a clear trend towards the redistribution of traffic by 30 min period. The growth in congestion, the greater use of flextime and other flexible working arrangements, and the high cost of housing near employment centers have all convinced increasing number of commuters to adjust their departure times. Our staff have authored a number of papers on the development of different congestion measures and the use of feedback to allow congestion to influence departure times. One approach to this task involves iterating the model: an initial run establishes a preliminary level of congestion and that data is used to modify the percentage of travellers in the peak periods.

Task 10 Deliverables

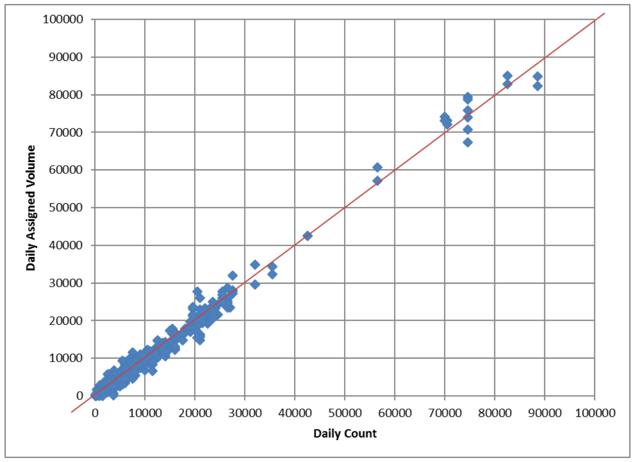
- Technical Memo summarizing the trip assignment assumptions and methodologies, as well as a peak spreading adjustment process, if applicable.

Task 11 Base Year Model

11.1 Base Year Model Validation

The RFP mentions validating to 2018 counts. If a sufficient number of traffic counts are available for 2018, this is suitable, otherwise the base year should be set to the most recent year when counts are available. As noted in Task 2.2, we will identify locations where additional counts might be needed. At the start of the project, we will propose a set of validation accuracy guidelines for daily and peak hour traffic. This usually includes statistics such as root-mean-square error (RMSE), volume/count ratios by facility type, and volume/count plots (see Figure 5). Once we reach agreement with City staff on these guidelines, they will become the targets to be met in this task. The regional model will be validated to daily counts.

Figure 5
Assignment Validation Scatterplot



We have developed a process that we call "Adaptable Assignment (AA)" that aids in assignment validation. This process consists of the following:

- Adjust the model (rates, trip lengths, mode share, network coding, etc.) until the assigned volumes match the counts as closely as possible.
- Perform extensive quality control on the count data, to ensure the consistency of counted volumes.
- Use an ODME process such as Cube Analyst Drive to modify the model's vehicle trip table so that the resulting assignments better match the counts.
- Subtract the starting trip table from the modified trip table to establish a "delta table" which is then added to the model's output for forecasting.

This process has produced very good results in many studies, but it must be used with caution. For example, it might not be suitable (or would need adjustment) in the case of zones that will have a large forecasted change in land use.

11.2 Performance Measures

A traffic assignment produces a great deal of information and it is very difficult for people to learn much from staring at a plot of link volumes. We have found that decision-makers and the public require summary reports that boil the results of an assignment down to a relatively few figures and compare the results of different model runs. We have developed a particular report that most people find easy to understand and which readily answers the question "Did things get better or worse?". Figure 6 shows an example of this report. It is simple to program this as a Cube Voyager Network step that is produced automatically after each model run. This can be easily customized to meet the needs of City staff. Cube also has an extensive array of built-in reporting capabilities that can easily produce a variety of report-ready graphics from a model run.

Figure 6
Assignment Summary Report

Roadway Lane-Miles by Functional Class and Daily Level of Service

Model Run: Task 13 2040 Base

	Level of Service A	B	C	D	E	F	Total	% of Total
Freeway/Ramp	43	21	92	32	113	4	305	14%
Prin Art/Pkwy	76	122	168	84	37	3	490	22%
Min Art	155	201	104	17	32	1	510	24%
Maj Coll	40	92	90	73	82	7	384	17%
Min Coll	102	106	102	48	52	19	429	20%
Local/Town St	34	13	8	5	8	1	69	3%
Total	450	555	564	259	324	35	2,187	
% of Total	21%	25%	26%	12%	14%	2%	100%	

Base: Task 13 2015

	Level of Service A	B	C	D	E	F	Total	% of Total
Freeway/Ramp	40	38	69	19	70	0	236	13%
Prin Art/Pkwy	35	126	103	19	7	0	290	17%
Min Art	150	110	42	25	16	0	343	19%
Maj Coll	27	84	100	79	31	4	325	19%
Min Coll	168	112	134	29	50	0	493	28%
Local/Town St	50	8	6	3	7	0	74	4%
Total	470	478	454	174	181	4	1,761	
% of Total	27%	27%	26%	9%	11%	0%	100%	

VMT/VHT/Speed Summary#

	Task 13 2040	Task 13 2015	Difference	Pct Diff.
Vehicle-mi of travel	16,151,000	9,992,000	6,159,000	62%
Congested veh-hours	453,000	267,000	186,000	70%
Free-flow veh-hours	365,000	230,000	135,000	59%
Delay (aggregate hrs)	88,000	37,000	51,000	138%
Pct Congested Delay	24%	16%	8%	50%
Avg Congested Speed	36	37	-2	-5%

Task 11 Deliverables

- A validation memorandum summarizing the validation assumptions, criteria, methodologies, as well as the validation report for the a.m, and p.m. peak hours, and daily.
- Maps/plots and tables illustrating the differences in the forecasted volumes as compared to the traffic counts for all locations that have traffic counts.

Task 12 Travel Forecasts

12.1 Buildout Forecast

We will work with City staff to establish one “buildout” land use and transportation scenario, as described in sections 4.3, 5.2, and 6.2. In addition, we will obtain data on future external travel from the VTA model. It is important to double-check the consistency of the land use and external trip forecasts to ensure that there are enough City residents and non-resident commuters to fill the forecasted jobs, and vice-versa. It is also important to ensure that the land use and transportation facility forecasts are reasonable and logical. Our experience is that it makes no sense to input illogical conditions to a travel model and if that occurs, it should be no surprise if the model produces illogical results.

12.2 Forecasts by Year

We will work with City staff to create a reasonable land use scenario for a forecast year such as 2050, or as otherwise indicated in the City's long-range plan documents. We will write Cube Voyager scripts that allow the user to easily prepare the model inputs for any year between 2018 and 2050. These scripts will interpolate the land use by zone (with user overrides as needed) and will select future roadway projects from the network database. We anticipate that the City will continue to use our Application Manager user interface which greatly simplifies the organization of input data and the application of the model.

Task 12 Deliverables

- Maps/plots of Buildout scenario road network, showing road types, lanes and speeds.
- Maps/plots of Buildout scenario forecasted traffic volumes.
- Maps/plots showing the difference in forecasted traffic volumes between Base Year and Buildout scenarios.
- Summary table of Base Year and Buildout scenario performance measures.
- A memorandum summarizing the assumptions and methodology used to set up and to perform a forecast for any year of interest.

Task 13 Other Model Outputs

13.0 Detailed Assignment Process

As noted above, the City has two different analysis needs which we are proposing to address with a hybrid process. The discussion in Tasks 7-12 focused on the regional model. In addition, we see the need for a more detailed assignment process in order to provide the level of modelling required for TIA work. This would use the detailed zone system described in Task 3. The regional model's trips would be subdivided to the smaller zones based on City land parcel data if available. Satellite photo imagery, Census data, and our own Streetlytics O/D data are other options. The strategic model vehicle trip tables by period will be subdivided by more detailed time period, such as 10-20 minutes and assigned to the detailed network using a dynamic traffic assignment (DTA) process such as Cube Avenue. If the City prefers not to purchase Avenue, we would examine other options using Cube Voyager, such as a "pseudo-DTA" process using finer time slices and an approximation of queuing. We will also create a post-processing technique to adjust the detailed trip table to more closely match the count data. This will be an origin/destination matrix estimation process either using Cube Analyst Drive or a customized Cube Voyager methodology, as described above. The DTA process will be validated to traffic counts and turning movement volumes on an hourly basis.

13.1 Intersection Volumes

The results of the detailed assignment process will be sufficiently accurate within the City to allow the reasonable estimation of turning volumes at all major intersections. We already have Cube scripts that automatically reformat the output turn volumes for input to other programs, such as Synchro, or for reporting, as shown in Figure 7. If it should prove necessary to include manual post-processing of the model's turn volumes, such processing will be documented.

Figure 7
Turn Volume Report

```
 Westwood Valley Traffic Study, Sioux Falls, SD
                  W Corridor & 26th St

                               N Node  2618
                             |                   |
                             |     530      1265 |
                             |   45              |
                             | |   345           |
                             | |    |   140      |
                             | |    |   |        |
          ___________________|<┘    V   └>       |_________________________
              95                                 ^
     W                       ^                   └------   70        E
     Node          235 ------┘       Node        <------   25   155  Node
     2793    400   115 ------>       2612        ┌------   60        2790
                    50 ------┐                   V
                             V                                 375
         ____________________        <┐   ^    ┌> _________________________
          Turn Penalties     |         |   |    | | Critical Lane Analysis
                  =   .0     |        25  |    | | N-S:   415 SB
                  =   .0     |           960  | |       1220 NB
                  =   .0     |               120| E-W:   123 EB
                  =   .0     |   455      1105   |        248 WB
                  =   .0     |                   | Critical Vol:  1468
                               S Node  2803       OVER  CAPACITY
```

13.2 Select Link Analysis

We will write Cube scripts to perform select link/zone analysis. The output of this step can take several forms. In its basic definition, select link analysis outputs a zone-to-zone matrix of trips that use the selected link(s). This is generally too much data to use directly, so depending on the application, this matrix is typically either summarized as trip ends by zone or as O/D movements by district. It is also possible to output select link analysis as a bandwidth plot of link volumes throughout the network, that use the selected link(s). Select zone analysis is a version of select link assignment, in which the trips that leave from or arrive to a specific zone or group of zones, is tracked through the network. We will develop a process of identifying the trips that each O/D pair contribute to any selected turning movement.

13.3 Traffic Impact Analysis

The kind of analysis described in Subtask 13.2 is particularly helpful in supporting TIAs and impact fee calculations. It is possible in Cube to isolate a specific development, identify that development's new trips, and calculate the share of those trips on every link and intersection. The cost of improving those links and intersections can then be more equitably allocated to a specific development.

We will set the model up so that it can use the VTA TIA guidelines. This includes procedures to track a development's trips through the network and to use the model's volumes to identify those intersections that are most likely to be affected by a development.

Task 13 Deliverables

- A memorandum summarizing the assumptions and methodology used to automate the process to report the forecasted intersection turning volumes from the model. The memorandum shall also include any post processing steps to develop the forecasted turning volumes.
- The forecasted Buildout turning volumes in twelve turning movement format for the a.m. and p.m. peak hours.
- A memorandum summarizing the assumptions and methodology used to select study intersections for TIA using the travel demand model.

Task 14 VMT Analysis

14.1 VMT Reporting

It is a simple matter to report VMT for a particular scenario. VMT is calculated for every link on every model run and the data for any scenario can be subtracted from a base case to determine the change in VMT. Using the techniques described in Task 13, it is also simple to track changes in VMT from a specific development and to relate this to the land use in that development (households or employees, for example). This can be written as a Cube Voyager script that runs automatically for each model application.

14.2 VMT Map

VMT is calculated for each link and since each link is associated with a specific zone, it is very easy to summarize VMT by zone and to automatically create a thematic map that presents various ranges of VMT by zone (TAZ) in Esri format. This file would be compatible with the City's other GIS layers.

14.3 VMT Evaluation Tool (Optional)

Based on the rules contained in SB 743 and the associated CEQA Guidelines, we would develop Cube Voyager scripts that would report VMT, VMT per capita, and VMT per employee and allow these to be compared to any particular base case. It is clear that a multi-modal tour-based travel model such as this one is the most accurate method of calculating VMT, because it directly accounts for the major factors that affect VMT, as identified in Appendix 2 of the CEQA Guidelines. We will work with City staff to resolve certain issues regarding VMT calculation, such as how best to calculate intrazonal VMT and how to ensure that the results are consistent with other VMT estimation techniques, such as the VMT estimation tools created by ARB and VTA. We would also create a separate step in Application Manager that would allow City staff to apply this tool easily.

Task 14 Deliverables

- A memorandum summarizing the assumptions and methodology used to determine VMT using the model output.
- A GIS database containing the existing and forecasted VMT for three land use types (office, residential, and retail) by TAZ within the City of Sunnyvale.
- A VMT Evaluation Tool (Optional Task)
- A memorandum summarizing the assumptions and methodology used to evaluate VMT for proposed land use development projects. (Optional Task)

Task 15 Documentation and Training

15.1 Model Documentation

We will prepare two documents: a Calibration Report and a User's Guide. The Calibration Report documents the development of the model system, including the sources of observed data, the assumptions, and the techniques used to obtain the model parameters and relationships. It documents the calibration and validation of the entire model chain. It also covers the development of the base year and forecast input data and the results of model testing. The User's Guide explains not only how to apply the model but also how to create the input data and how to interpret and use the model outputs. The documentation and all model input and output files will be turned over to City staff.

15.2 Training

We will conduct an on-site two-day training for City staff. This will cover basic Cube usage as well as the details of the Sunnyvale Travel Demand Model. We will provide up to 8 hours of follow-up training.

Task 15 Deliverables

- Draft Model Calibration Report with two complete sets of data and text files required to run the model to be delivered on DVD or USB drive
- Final Model Calibration Report with two complete sets of data and text files required to run the model to be delivered on DVD or USB drive.
- Model training presentation.
- Draft Model User Guide.
- Final Model User Guide.

Task 16 Meetings

16.1 Staff Meetings

We will attend a project kick-off meeting and will participate in monthly progress meetings by webinar. In addition, we will attend up to four additional meetings in person with City staff, including preparation of meeting agendas and minutes. We will attend up to an additional five meetings by telephone or web-based conference call.

16.2 Presentations

We will attend up to three meetings to give presentations on project progress and results to key City decision-makers.

Task 16 Deliverables

- Meeting agendas and minutes.
- Presentations to Advisory Board/City Council.

EXHIBIT A-1
PROJECT SCHEDULE

	Task	Month Jul-2019	Aug-2019	Sep-2019	Oct-2019	Nov-2019	Dec-2019	Jan-2020	Feb-2020	March-2020
1	Project Management	■	■	■	■	■	■	■	■	■
2	Existing Data	■								
3	Traffic Analysis Zones	■								
4	Land Use Inputs		■							
5	Roadway Network		■	■						
6	Transit Network			■						
7	Trip Generation				■	■				
8	Trip Distribution				■	■				
9	Mode Choice, Stops, ToD					■	■			
10	Assignment						■			
11	Validation							■		
12	Forecasting								■	
13	Other Outputs							■	■	
14	VMT Reporting								■	
15	Documentation, Training									■
	Milestone Reports	Yes		Yes		Yes		Yes		Yes

EXHIBIT B
COMPENSATION SCHEDULE

Tasks		Labor									Subconsultants						ODCs	Total
Task #	Task Description (Change task titles as detailed in the scope of work)	Project Manager	Senior Consultant	Senior Engineer	Senior Engineer	Title	Title	Title	Total Hours	Total Labor Costs	Survey	Geotech..	Title	Title	Title	Title	Other Direct Costs	Total Fee
		Bill Allen	Chris Simons	Ahmed Mohideen	Filippo Contiero						Conslt. Name	Conslt. Name	Conslt. Name	Conslt. Name	Conslt. Name	Conslt. Name		
		$183	$246	$132	$119						Fee/Hr or LS	Fee/Hr or LS	Fee/Hr or LS	Fee/Hr or LS	Fee/Hr or LS	Fee/Hr or LS		
1	Project Work Plan and Management										-	-	-	-	-	-		
1.1	*Project Management*	24		8					32	$5,448								$5,448
1.2	*Kick-off Meeting*	24	16						40	$8,328							$1,750	$10,078
1.3	*Check-in Meetings*	36	16	16	16				84	$14,540								$14,540
2	Existing Data																	
2.1	*Existing Documents*	4	4	16					24	$3,828								$3,828
2.2	*Existing Count Data*	16		0	16				32	$4,832								$4,832
3	Develop Traffic Analysis Zone (TAZ) System	24		16	56				96	$13,168								$13,168
4	Develop Land Use Data Inputs																	
4.1	*Existing Land Use Inventory*	16		24	8				48	$7,048							$4,000	$11,048
4.2	*Approved/Pending Land Use*	8		24					32	$4,632								$4,632
4.3	*Buildout Land Use*	16		24					40	$6,096								$6,096
4.4	*Review of TAZ Map for Consistency with Project List*	4		8					12	$1,788								$1,788
4.5	*Land Use Assumptions for Neighboring Cities*	8							8	$1,464								$1,464
5	Develop Roadway Network																	
5.1	*Existing Roadway Network*	16		4	48				68	$9,168								$9,168
5.2	*Future Roadway Network*	8			16				24	$3,368								$3,368
6	Develop Transit Network																	
6.1	*Existing Transit Network*	8			32				40	$5,272								$5,272

6.2	*Future Transit Network*	8			12				20	$2,892								$2,892
7	Trip Generation																	
7.1	*HH Synthesis*	24							24	$4,392								$4,392
7.2	*Tour Frequency*	32							32	$5,856								$5,856
8	Trip Distribution																	
8.1	*Destination Choice*	32							32	$5,856								$5,856
9	Mode Choice																	
9.1	*Estimate Mode Choice/Vehicle Occupancy*	32							32	$5,856								$5,856
9.2	*Intermediate Stops*	16							16	$2,928								$2,928
9.3	*Time of Day*	8							8	$1,464								$1,464
10	Trip Assignment																	
10.1	*Trip Accumulation*	4							4	$732								$732
10.2	*Regional Assignment*	8	0	0	28				36	$4,796								$4,796
11	Base Year Model																	
11.1	*Base Year Model Validation*	20	0	0	24				44	$6,516								$6,516
11.2	*Base Year Performance Measures*	8		0	16				24	$3,368								$3,368
12	Travel Forecasts																	
12.1	*Buildout Forecasts*	8		0	24				32	$4,320								$4,320
12.2	*Future Forecasts by Study Year*	8		0	24				32	$4,320								$4,320
13	Other Model Outputs																	
13.0	*Detailed Assignment Process*	8	40	8	8				64	$13,312								$13,312
13.1	*Intersection Turning Volumes Linkage*	4		0	4				8	$1,208								$1,208
13.2	*Select Zone/Select Link Analysis*	4		0	4				8	$1,208								$1,208
13.3	*Select Study Intersections for Traffic Impact Analysis*	0		24					24	$3,168								$3,168
14	Vehicle-Miles Travel Reporting and Evaluation Tool																	
14.1	*VMT Reporting*	4		0	12				16	$2,160								$2,160
14.2	*VMT Map by TAZ*	0		0	12				12	$1,428								$1,428
15	Model Documentation, User Guide, and Training																	

15.1	*Model Documentation*	32		4					36	$6,384								$6,384
15.2	*Training*	0		44					44	$5,808								$5,808
16	Meetings and Presentations																	
16.1	*Meetings with City Staff (4)*	48		16					64	$10,896							$6,400	$17,296
16.2	*Presentations to Advisory Board/City Council (3)*	48			12				60	$10,212							$4,350	$14,562
	Proposal Subtotal	568	76	236	372	0	0	0	1,252	$198,060	$0	$0	$0	$0	$0	$0	$16,500	$214,560
	Optional Services																	
4.6	School Zones (Optional Task)	8	-	16	-	-	-	-	24	$3,576	-	-	-	-	-	-	-	$3,576
8.2	Trip Distribution Assumptions for School Purpose (Optional Task)	8	-	-	-	-	-	-	8	$1,464	-	-	-	-	-	-	-	$1,464
10.3	Peak Spreading (Optional Task)	4	16	8	-	-	-	-	28	$5,724	-	-	-	-	-	-	-	$5,724
14.3	VMT Evaluation Tool (Optional Task)	8		0	32	-	-	-	40	$5,272	-	-	-	-	-	-	-	$5,272
	--------	-	-	-	-	-	-	-	0	$0	-	-	-	-	-	-	-	$0
	Total Optional Services	28	16	24	32	0	0	0	100	$16,036	$0	$0	$0	$0	$0	$0	$0	$16,036
	Total Including Optional Services	596	92	260	404	0	0	0	1,352	$214,096	$0	$0	$0	$0	$0	$0	$16,500	$230,596
	Notes:																	
1	The cost estimate for each element in Detailed Scope of Work shall be included in the appropriate corresponding required task.																	

EXHIBIT C
INSURANCE REQUIREMENTS FOR CONSULTANTS

Consultant shall procure and maintain for the duration of the contract insurance against claims for injuries to persons or damages to property which may arise from or in connection with the performance of the work by the Consultant, his agents, representatives, or employees.

Minimum Scope and Limits of Insurance. Consultant shall maintain limits no less than:

1. **Commercial General Liability**: $1,000,000 per occurrence and $2,000,000 aggregate for bodily injury, personal injury and property damage. ISO Occurrence Form CG 0001 or equivalent is required.

2. **Automobile Liability**: $1,000,000 per accident for bodily injury and property damage. ISO Form CA 0001 or equivalent is required.

3. **Workers' Compensation** Statutory Limits and **Employer's Liability**: $1,000,000 per accident for bodily injury or disease.

4. **Errors and Omissions** Liability Insurance appropriate to the Consultant's Profession: $2,000,000 per claim.

Deductibles and Self-Insured Retentions

Any deductibles or self-insured retentions must be declared and approved by the City of Sunnyvale. The consultant shall guarantee payment of any losses and related investigations, claim administration and defense expenses within the deductible or self-insured retention.

Other Insurance Provisions

The **general liability** policy shall contain, or be endorsed to contain, the following provisions:

1. The City of Sunnyvale, its officials, employees, agents and volunteers are to be covered as additional insureds with respects to liability arising out of activities performed by or on behalf of the Consultant; products and completed operations of the Consultant; premises owned, occupied or used by the Consultant; or automobiles owned, leased, hired or borrowed by the Consultant. The coverage shall contain no special limitations on the scope of protection afforded to the City of Sunnyvale, its officers, employees, agents or volunteers.

2. For any claims related to this project, the Consultant's insurance shall be primary. Any insurance or self-insurance maintained by the City of Sunnyvale, its officers, officials, employees, agents and volunteers shall be excess of the Consultant's insurance and shall not contribute with it.

3. Any failure to comply with reporting or other provisions of the policies including breaches of warranties shall not affect coverage provided to the City of Sunnyvale, its officers, officials, employees, agents or volunteers.

4. The Consultant's insurance shall apply separately to each insured against whom claim is made or suit is brought, except with respect to the limits of the insurer's liability.

5. Each insurance policy required by this clause shall be endorsed to state that coverage shall not be suspended, voided, cancelled by either party, reduced in coverage or in limits except after thirty (30) days' prior written notice by certified mail, return receipt requested, has been given to the City of Sunnyvale.

Acceptability of Insurers

Insurance is to be placed with insurers with a current A.M. Best's rating of not less than A:VII, unless otherwise acceptable to the City of Sunnyvale.

Verification of Coverage

Consultant shall furnish the City of Sunnyvale with original a Certificate of Insurance effecting the coverage required. The certificates are to be signed by a person authorized by that insurer to bind coverage on its behalf. All certificates are to be received and approved by the City of Sunnyvale prior to commencement of work.