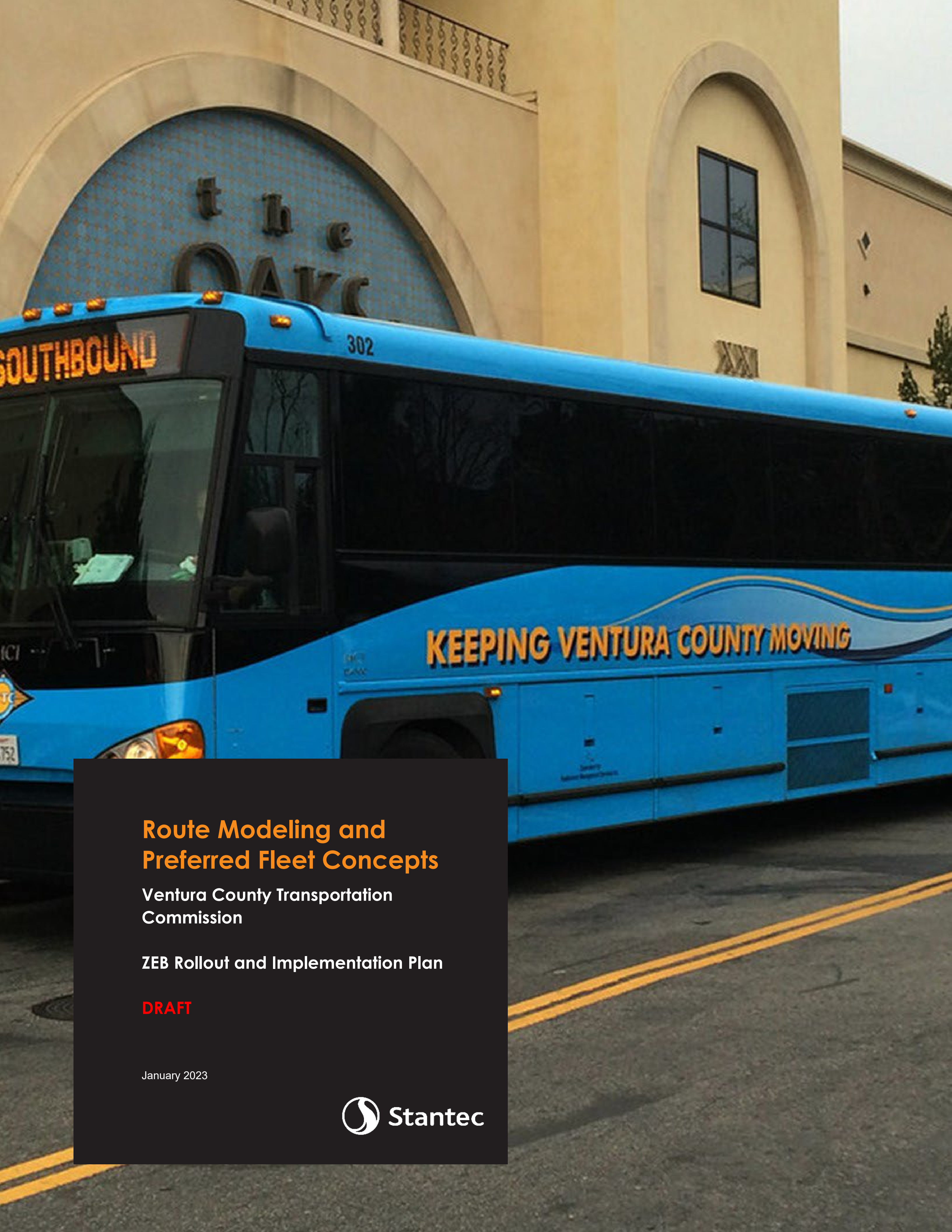

Route Modeling and Preferred Fleet Concepts

Ventura County Transportation Commission

ZEB Rollout and Implementation Plan

DRAFT

January 2023

Stantec

Route Modeling and Preferred Fleet Concepts

ZEB Rollout Plan and Implementation Strategy

DRAFT

January 20, 2023

Prepared for:

Ventura County Transportation Commission

Prepared by:

Stantec Consulting Services Inc.

ROUTE MODELING AND PREFERRED FLEET CONCEPTS

DRAFT

Release Version

Rev.	Description	Date
0	Draft Report Issued to VCTC	01/20/2023
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1	Revised Report Issued to VCTC	
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Appendix A – Driving Cycle Assignments

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Abbreviations

APCD	Air Pollution Control District
BE	Battery-electric
BEB	Battery-electric bus
CARB	California Air Resources Board
CNG	Compressed natural gas
FCEB	Hydrogen fuel cell-electric bus
GCTD	Gold Coast Transit District
ICT	Innovative Clean Transit
NREL	National Renewable Energy Laboratory
O&M	Operations and maintenance
SBCAG	Santa Barbara County Association of Governments
SCCAB	South Central Coast Air Basin
SCE	Southern California Edison
SOC	State of charge
VCTC	Ventura County Transportation Commission
ZE	Zero emission
ZEB	Zero-emission bus

1.0 PROJECT OVERVIEW AND INTRODUCTION

Ventura County Transportation Commission (VCTC) oversees public transit fixed-route and demand response services in eastern Ventura County as well as regional commuter services. VCTC carried over 252,000 unlinked passenger trips in 2021[1]. VCTC's services are organized under two umbrellas:

- Intercity service, which provides regional commuter services throughout Ventura County and to Santa Barbara County, and
- Valley Express service, which provides local fixed route, ADA paratransit, and general-purpose dial-a-ride to the eastern Ventura County communities of Santa Paula, Fillmore, and Piru.

VCTC currently owns a fleet of 51 vehicles—36 motorcoaches for Intercity service and 15 cutaways for Valley Express service. VCTC owns its fleet, and each fleet is housed at a separate operations and maintenance facility owned by VCTC's third-party operators. VCTC is a part of the Ventura County Air Pollution Control District (APCD), South Central Coast Air Basin (SCCAB), and Southern California Edison (SCE) utility territory.

With a service area population of 209,877 and fewer than 50 vehicles in peak service, VCTC is classified as a small transit agency under the Innovative Clean Transit (ICT) mandate and is required to submit a zero-emission (ZE) rollout plan to the California Air Resources Board (CARB) by July 1, 2023[2].

This report provides an overview of the route modeling and bus simulation methodology and presents the results of this modeling to understand the feasibility of transitioning VCTC's operations to different ZE options. Based on these results, we present a discussion of the different ZE fleet solutions and the pros and cons of different fleet concepts. The report concludes with a professional recommendation on the optimal ZEB fleet composition for VCTC's Intercity and Valley Express services.

2.0 EXISTING CONDITIONS SUMMARY

The existing conditions report provided a comprehensive review of VCTC's existing conditions, encompassing operations, facilities, and finances to lay the groundwork for the modeling and understand current operating conditions[3].

Major findings from the existing conditions report that will affect the ZEB transition include:

[1] 2021 NTD agency profile.
[2] CARB ICT defined large transit agencies as operating in "an urbanized area with a population of at least 200,000 as last published by the Bureau of Census before December 31, 2017 *and* has at least 100 buses in annual maximum service." Agencies that do not meet this definition are categorized as small transit agencies.
[3] Throughout this report, "current" refers to 2022 conditions unless otherwise stated.

- **VCTC operates in a vast and diverse service area.** Intercity operates in more urban areas, providing long-distance commuter service to major trip generators throughout Ventura and Santa Barbara counties with routes traveling largely along highways to connect different destinations. Valley Express provides service to the smaller, less dense communities in eastern Ventura County. **Overall, VCTC's vehicles operate across long distances.**

- **VCTC's current fleet is made up of motorcoaches for Intercity service and cutaways for Valley Express service** (Table 1). Intercity buses are all diesel-powered with an average fleet age of 6.6 years. Valley Express cutaways are gasoline-powered and are 7 years old on average.

Table 1: Current revenue fleet composition

In-Service Year	Quantity	Make	Vehicle Type	Seating Capacity	Fuel type	FTA minimum useful life[4]	Current age[5]	Service type
2014	14	Cummins	Motorcoach	57	Diesel	14 years	8 years	Intercity
2015	11	Cummins	Motorcoach	53	Diesel	14 years	7 years	Intercity
2016	3	Cummins	Motorcoach	57	Diesel	14 years	6 years	Intercity
2019	3	Cummins	Motorcoach	57	Diesel	14 years	3 years	Intercity
2013	1	Volvo	Motorcoach	53	Diesel	14 years	9 years	Intercity
2019	4	Volvo	Motorcoach	53	Diesel	14 years	3 years	Intercity
2015	5	Glaval	Cutaway	12	Gasoline	10 years	7 years	Valley Express
2015	5	Glaval	Cutaway	16	Gasoline	10 years	7 years	Valley Express
2015	5	Arboc	Cutaway	23	Gasoline	10 years	7 years	Valley Express

When considering ZE alternatives, there are limited options for VCTC to consider. Motorcoaches have fewer ZE alternatives when compared to options available for standard buses that are generally currently limited to BEBs. Cutaway vehicles are also currently available as BEBs only. **Overall, the choices of ZEV alternatives for the types of vehicles operated by VCTC are limited and still immature.**

- **VCTC, in partnership with the Santa Barbara County Association of Governments (SBCAG), was awarded funding to purchase five BE motorcoaches.** These BEBs are currently being manufactured by BYD in Lancaster, CA and should be in operation sometime in 2023 (Figure 1). These vehicles are anticipated to have a range of 175 miles and are to be charged at a shared facility in Goleta. While VCTC will be operating these vehicles likely on the Coastal Express route so charging will be a possibility in Goleta, a challenge remains to ensure that the BEBs will have sufficient charge to make return trips to Oxnard and Camarillo while also making outbound trips. In other words, because VCTC is not planning to install chargers at its

[4] https://olga.drpt.virginia.gov/Documents/forms/DRPT%20Asset%20Useful%20Life%20Chart.pdf
[5] Current age determined from in-service year

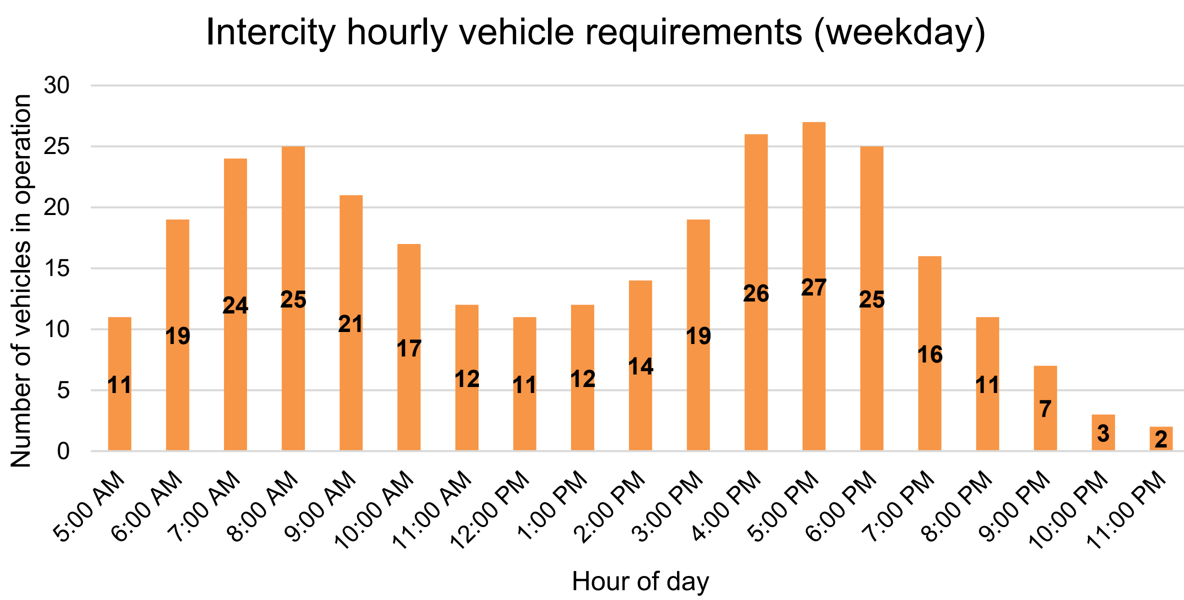
facility in Camarillo, VCTC needs to understand the operating constraints of these vehicles and whether charging at Goleta is sufficient and operationally viable.

Figure 1: VCTC's BEB under production

- For Intercity services, a typical service day sees more vehicles in service during the morning and afternoon peaks, reflective of typical commuter services[6]. Hourly vehicle requirements are the highest at 5-6 pm with 27 vehicles required for service (Figure 2).

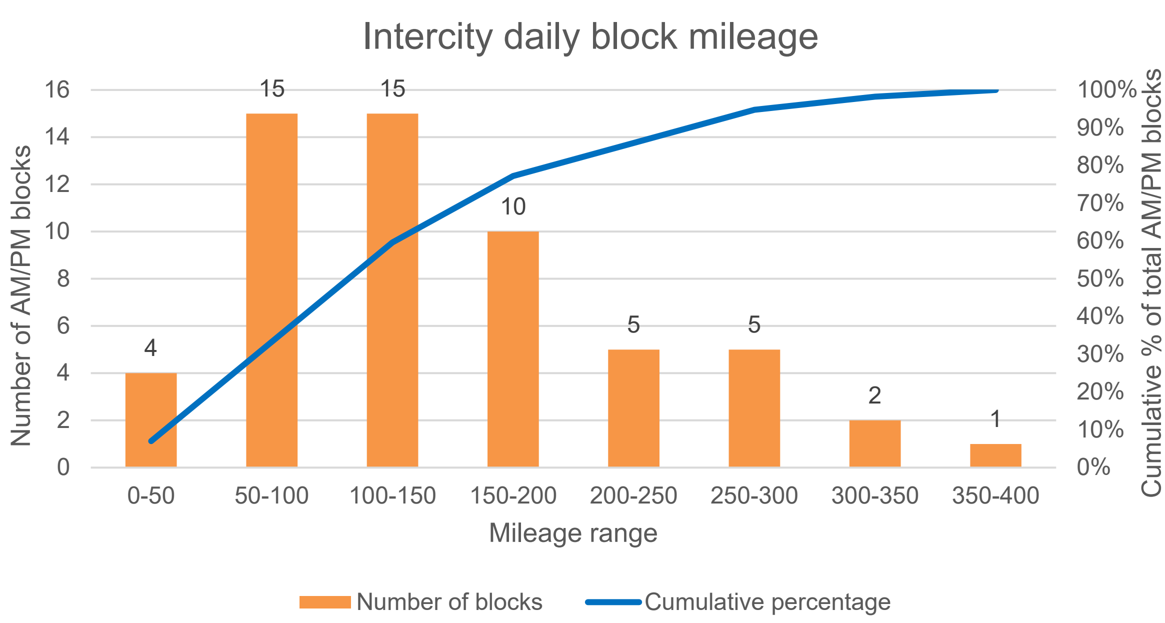
[6] Representative data from summer/fall 2022 were analyzed.

Figure 2: Hourly vehicles in operation (Intercity)



- Understanding scheduling and operating practices is important because it lets us understand an agency's blocking practices, how long blocks are, and how blocks are assigned to vehicles. This translates to how long vehicles are out in revenue operation and, from a modeling perspective, helps us understand if current blocks can be completed with ZE equivalents. **Figure 3 shows that 60% of all Intercity blocks have mileages under 150 miles. The maximum block length is approximately 385 miles.**

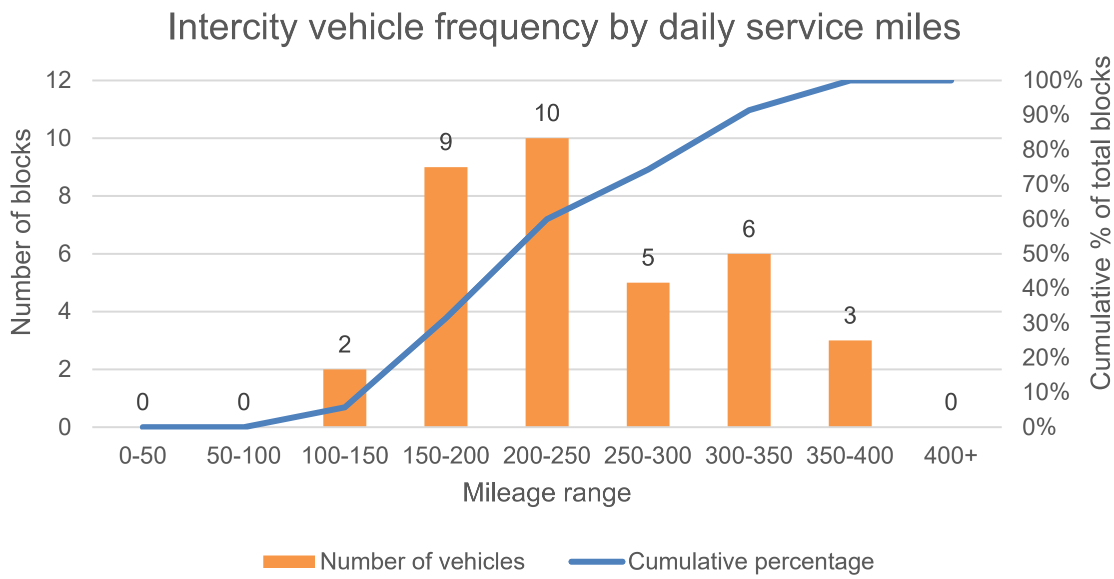
Figure 3: Block frequency by daily service miles



- Twenty-two out of 35 vehicles (or 63% of vehicles in operation) complete two blocks on an average day. When considering vehicle assignments, the total mileage increases significantly (Figure 4) compared to block-only mileage. **This shows that 40% of vehicles travel more than 250 miles in a day, which would pose a challenge for BE implementation if vehicles were to charge solely overnight, as the current range of BE coaches vary between 170 and 230 miles per charge[7].**

[7] Based on quotes from MCI: [Features - MCI (mcicoach.com)]

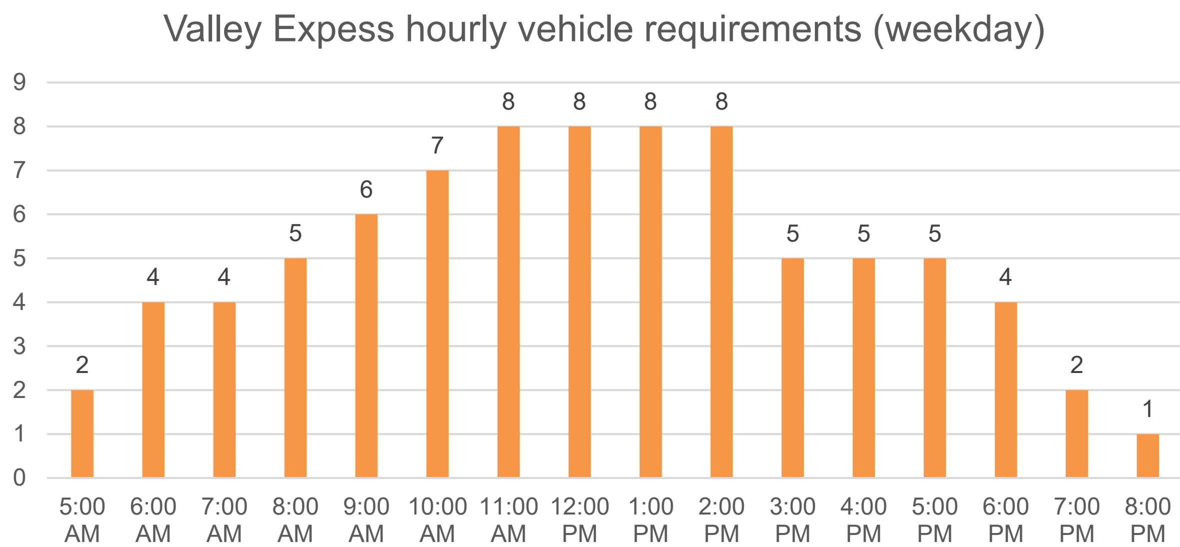
Figure 4: Vehicle frequency by daily service miles



- Valley Express service operates using a fleet of cutaways that are used for both fixed route and demand response services. Daily service is scheduled such that an operator can operate both fixed route and demand response in the same day, and due to the variable nature of demand response services, where there is no fixed schedule and service varies based on demand, it is important to capture this variation in the modeling. For the purposes of the existing conditions report, one representative service day was chosen to show an example of how Valley Express vehicles operate on an average day[8]. Figure 5 shows that service peaks from 11 am-2 pm, with eight vehicles in operation, and total hourly vehicle requirements fluctuate from one vehicle at 8 pm to eight vehicles during the midday. The bulk of service is during the midday period, and these vehicles are completing both fixed route and demand response services during this time.

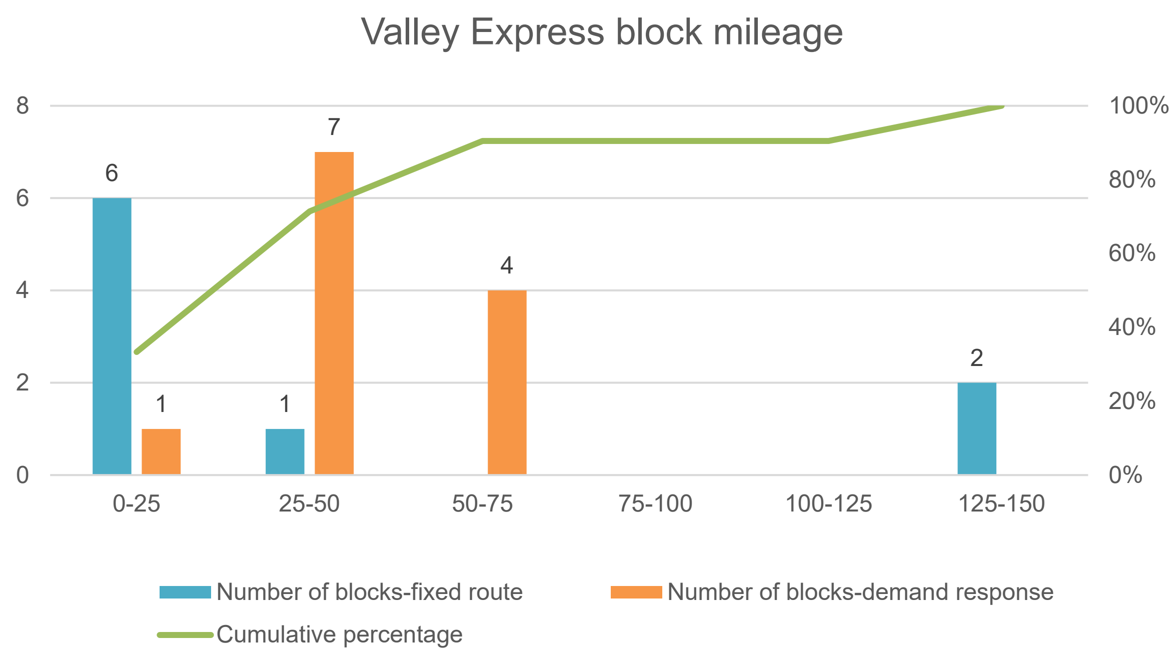
[8] Monday, August 22, 2022 was chosen as the representative service day.

Figure 5: Hourly weekday vehicle requirements for Valley Express services



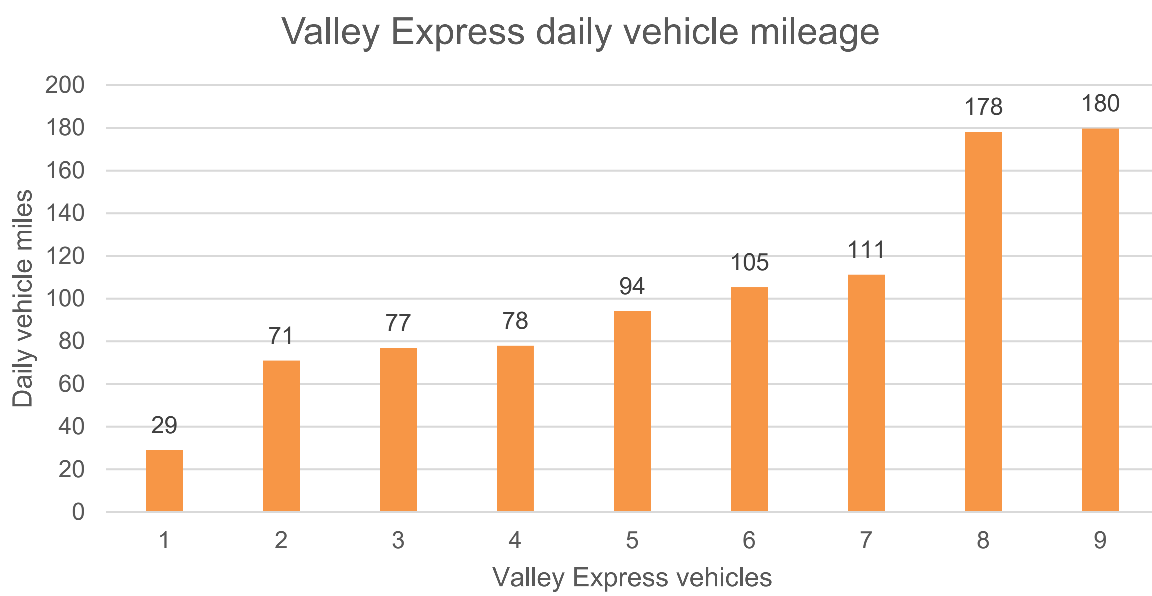
- Figure 6 shows Valley Express service broken out by block mileage, which is further broken down into fixed route and demand response block mileage. There is a close-to-even split between the number of daily blocks assigned to fixed routes (nine blocks) and demand response (12 blocks). **Fixed route block mileage shows a wider variation, with six blocks operating between zero and 25 miles, but two blocks operate over 125 miles. Demand response block mileage shows less variation, with all 12 blocks operating between 16 and 71 miles.**

Figure 6: Block frequency by daily service miles



- Figure 7 shows the daily mileage per vehicle when blocks are combined at the vehicle assignment level. When combined at the vehicle assignment level, **the average Valley Express vehicle is in service for 103 miles, compared to an average block length of 44 miles.** As range is more of an issue with smaller ZEVs, such as cutaways, these daily distances may be difficult to complete with ZE equivalents.

Figure 7: Valley Express daily vehicle mileage



- **VCTC does not own the operations and maintenance facilities for the Intercity service nor for the Valley Express service.** Both the Camarillo and Santa Paula facilities (for Intercity and Valley Express, respectively) largely appear in good working condition.
- Because VCTC does not own these facilities and because VCTC's contractors may change from time to time depending on contract award, **VCTC is unable to invest in the facility modifications that would be needed to accommodate ZEBs (chargers, electrical upgrades, hydrogen fueling, gas leak detection, etc.).**
    - To circumvent this challenge, VCTC and Gold Coast Transit District (GCTD) are exploring a potential partnership to allow VCTC access to GCTD's eventual hydrogen fueling infrastructure at its facility in Oxnard.
    - For Valley Express vehicles, developing a charging or fueling strategy is more complicated given the isolated nature of these services and the inability of VCTC to invest in the Santa Paula facility.

Overall, VCTC is unique in several aspects compared to other transit agencies—long routes and mileages, VCTC doesn't own its facilities, and the vehicle types VCTC operates have few ZE options—making ZEB transition planning uniquely challenging.

3.0 BUS MODELING AND ROUTE SIMULATIONS

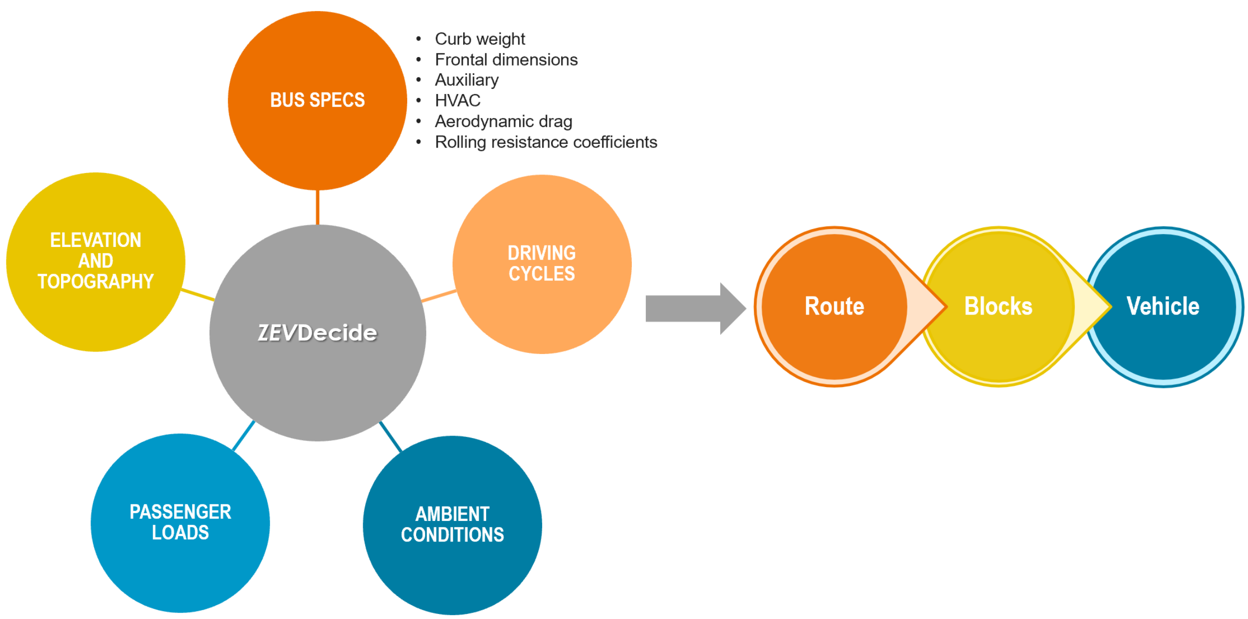
This section describes the process of the bus modeling and route simulation, including the inputs and methodology.

ZEVDecide is a modeling tool designed by Stantec to support transit agencies in transitioning to zero-emission fleets, and ultimately helps to answer the question: what is the feasible and ideal composition of ZEBs for my fleet?

Energy modeling uses a two-pronged approach to understanding ZEB feasibility. The two-pronged approach first examines route-level operations, and secondly, examines fuel economy by aggregating route-level outputs to provide block/vehicle level fuel/energy requirements. In this way, Stantec and VCTC will understand how different ZEB technologies perform under VCTC's operating conditions, providing a more realistic estimate of operating range and energy consumption that relying solely on OEM-stated ranges, ultimately informing technology selection.

Figure 8 provides a schematic overview of the modeling process. The predictive ZEB performance modeling depends on several inputs, such as actual passenger loads, driving dynamics, topography, vehicle specifications, and ambient conditions subject to the environment in which the agency operates.

Figure 8: Modeling overview

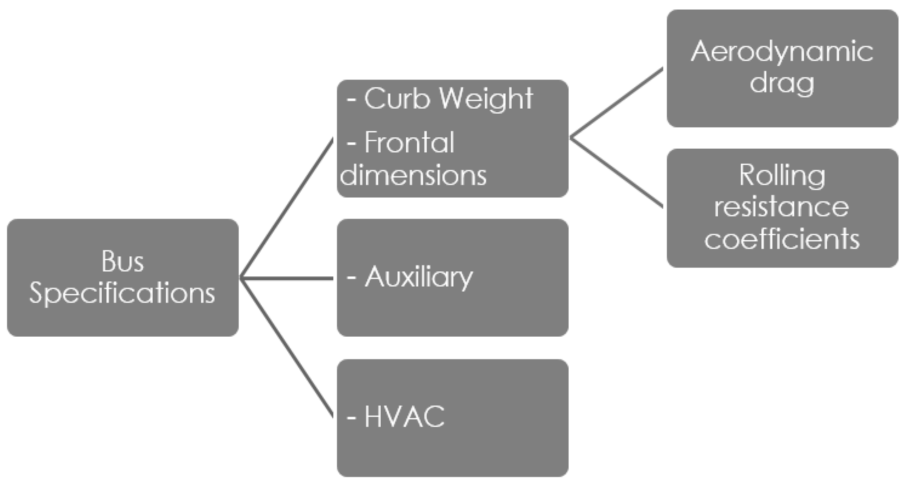


3.1 MODELING INPUTS

3.1.1 Bus Specifications

ZEVDecide's energy modeling process predicts ZEB drivetrain power requirements specific to given acceleration profiles. One key component to the modeling is the bus design or bus specifications that include curb weight and frontal dimensions (factors needed to account for aerodynamic drag and rolling resistance coefficients), auxiliary, and HVAC (Figure 9).

Figure 9: Detailed bus specification inputs



For Intercity service, the key motorcoach specifications used in the modeling process are detailed in Table 2. Given that hydrogen fuel cell motorcoaches are not commercially available in the US, certain assumptions were made in order to model such vehicle type. Available models of 40-ft low floor buses in the US are equipped with 37.5 kg of hydrogen tanks, therefore, this was the assumed tank size for a potential hydrogen coach. Additionally, the curb weight of the motorcoach was assumed to be similar to the weight of an electric coach since the chassis and the frame would be similar in size and the weight of the batteries is assumed to be equivalent to the weight of the fuel cell power plant. Lastly, while hydrogen fuel cell motorcoaches are not available in the US, these vehicles will likely be available in the future. Currently, the only available model that appears to market ready (yet not in revenue service) is the Hyzon 35-ft high-floor hydrogen fuel cell motor coach, equipped with at 35-kg tank and a stated range of 250 miles[9].

[9] https://www.hyzonmotors.com/vehicles/hyzon-high-floor-coach

Table 2: ZE motorcoach specifications for Intercity energy modeling[10]

Technology Type	BEB	FCEB
Battery/Tank	544 kWh	37.5 kg
Vehicle Length (ft.)	45	35
Curb Weight (lbs.)	47,000	47,000
Example Image		

Currently, few ZE cutaways have been tested and deployed to operate paratransit/demand response services. We modeled Valley Express service delivery with a battery-electric (BE) cutaway that has a 127-kWh battery. Valley Express operations were also modeled with FCE cutaways (13.5-kg tanks), though these vehicles are not currently commercially available. For modeling purposes, we assumed the hydrogen cutaways would be equipped with 13.5-kg tanks, similar to those on hydrogen passenger vans. Additionally, the curb weight for a hypothetical hydrogen cutaway was based on the incremental weight between a hydrogen and an electric van, given that the frame and chassis would be equivalent, the weight difference would relate to the extra weight from the fuel cell plant. Assumed vehicle specifications for Valley Express modeling are detailed in Table 3.

Table 3: ZE cutaway specifications for Valley Express energy modeling

Technology Type	BEB	FCEB
Battery/Tank	127 kWh	13.5 kg
Curb Weight (lbs.)	14,500	16,500

[10] Hydrogen vehicles are not currently commercially available.

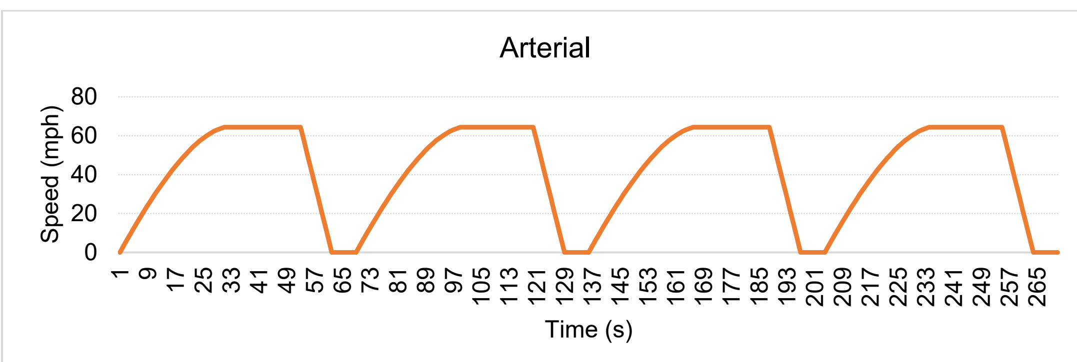
Technology Type	BEB	FCEB
Example image		

3.1.2 Representative Driving Cycles

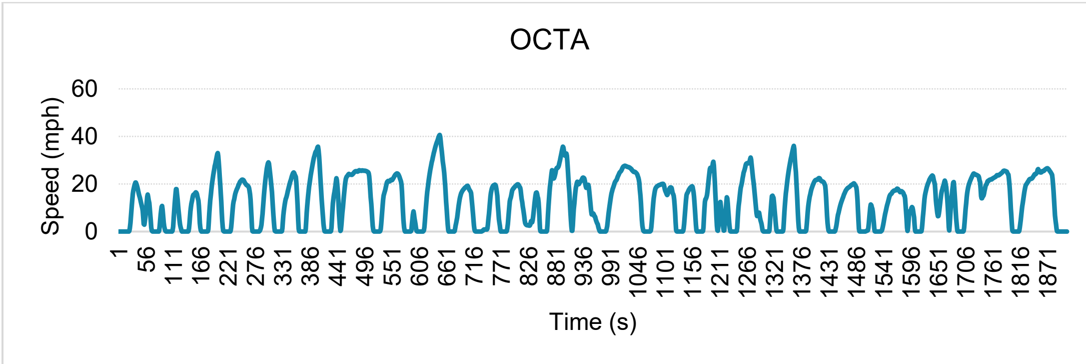
Assigning representative driving cycles, also called acceleration profiles or duty cycles, is the other major step in the energy modeling. A driving cycle is a speed versus time profile that is used to simulate the vehicle performance, and consequently, the energy use. Representative diving cycles were assigned to all routes based on Intercity operations and observed driving condition.

The driving cycles have been created from data collection of real-world operations or from chassis dynamometer tests and have been convened by the National Renewable Energy Laboratory (NREL) in a drive cycle database called DriveCAT[11] (examples shown in Figure 10).

Figure 10: Examples of two representative driving cycles



[11] NREL DriveCAT - Chassis Dynamometer Drive Cycles. (2019). National Renewable Energy Laboratory. www.nrel.gov/transportation/drive-cycle-tool



To assign driving cycles to VCTC's routes (both Intercity and Valley Express), we evaluated VCTC's routes in terms of average speed, route length, the number of stops and traffic levels. The suite of driving cycles and their key specifications considered for VCTC's routes are shown in Table 4.

Table 4: Driving cycles technical specifications (source: NREL)

Cycle Name	Max Speed (mph)	Avg. Driving Speed (mph)	Stops/min
Cycle A Mixed Traffic (OCTA)	40.63	15.67	0.97
Cycle B Arterial	40	29.7	0.89
Cycle C Freeway (UDDS)	58	28.23	0.79
Cycle D Medium Traffic	Confidential		
Cycle E Commuter	55	49.8	0.19

The complete classification of driving cycles to all routes is presented in Appendix A – Driving Cycle Assignments.

3.1.3 Passenger Loads

As the total weight of a ZEB impacts its performance, it is important to understand and capture passenger loads in the modeling process. To examine the impacts of passenger loads and its associated weight[12], VCTC provided data for each route detailing the passenger load for each route to be modeled. Based on this data, and to capture the variation of passengers onboard throughout the course of the day, all routes

[12] Estimated average passenger weight—170 lbs.

were modeled with a high passenger load, reflecting conditions when the bus is full to 75% of its seated capacity, and a low passenger load when the bus reaches 25% of its seated capacity.

3.1.4 Ambient Temperatures

The ambient temperature has a significant impact in the fuel economy of the ZEBs since it is directly related to the power output from the batteries required for the heating, ventilation, and air conditioning (HVAC) system.

Stantec developed a correlation between ambient temperature and power requirements from the HVAC system. For example, moderate daily temperatures (between 55 °F and 65 °F) can have a nominal power demand on the HVAC system of up to 4 kW. Colder temperatures (below 45 °F) or hotter temperatures (above 70 °F) can represent more strenuous loads of up to 12 kW. The power requirement for modeling purposes was set based on an annual average low temperature average of 46 °F[13].

3.1.5 Topography and Elevation

Given that portions of VCTC's service area are highly influenced by elevation and topography, it is important to account for the impacts of terrain and elevation on the energy efficiency of ZEBs. While the topography of western Ventura County is largely flat, varied topography can be seen elsewhere, and these elevation changes influence energy efficiency and subsequently expected ZEB performance.

The first step in the route elevation analysis is to determine the elevation gains and losses seen across VCTC's routes. Furthermore, the total elevation gains will inform the maximum and average grades across each route. From there, an analysis of elevation based on route alignments was undertaken for each route; Intercity routes are shown in Table 5, and Valley Express routes are shown in Table 6.

Table 5: Intercity elevation analysis

Route	Average slope	Max slope	Weighted average slope
50-Hwy 101	1.6%	5.7%	3.7%
52-Hwy 101	1.0%	5.7%	2.6%
52x-Hwy 101	1.7%	7.6%	3.0%
60-Hwy 126	1.0%	6.2%	2.1%
62-Hwy 126	1.0%	4.4%	2.2%
70-East County	2.4%	8.2%	4.0%
72-East County	1.9%	7.2%	4.3%
73-East County	2.1%	7.4%	3.9%
73x-East County	1.9%	8.5%	3.7%
77-Cross County Limited	1.1%	5.1%	2.5%

[13] US Climate Data https://www.usclimatedata.com/climate/oxnard/california/united-states/usca0819 and https://www.usclimatedata.com/climate/santa-barbara/california/united-states/usca1017

Route	Average slope	Max slope	Weighted average slope
80-Coastal Express	0.9%	5.7%	2.0%
80c-Coastal Express	1.2%	6.3%	1.9%
80x-Coastal Express	1.2%	5.7%	1.8%
81-Coastal Express	1.0%	4.3%	1.6%
81b-Coastal Express	1.0%	4.5%	1.6%
84-Coastal Express	0.9%	4.1%	2.0%
84u-Coastal Express	0.9%	5.5%	1.6%
85-Coastal Express	0.9%	5.2%	2.0%
85c-Coastal Express	0.9%	5.8%	1.1%
86-Coastal Express	0.9%	5.4%	1.5%
87-Coastal Express	0.9%	5.6%	2.1%
88-Coastal Express	1.0%	4.4%	1.6%
89-Coastal Express	0.9%	5.3%	2.0%
90-C St/CSUCI	1.0%	6.2%	1.9%
97-Cam Metrolink/CSUCI	2.4%	11.6%	4.6%
99-CSUCI	0.9%	6.4%	1.7%

Table 6: Valley Express elevation analysis

Route	Average slope	Max slope	Weighted average slope
Fillmore Loop	1.5%	4.7%	2.9%
Fillmore Tripper-AM Rio Vista	1.0%	5.2%	2.1%
Fillmore Tripper-PM Rio Vista	1.2%	4.8%	2.3%
Piru	1.2%	5.0%	2.2%
Santa Paula A	1.2%	8.7%	2.8%
Santa Paula B	2.3%	18.1%	6.0%
Santa Paula School Tripper	1.2%	7.6%	2.9%

Each route shapefile (derived from GTFS data) was downloaded in Google Earth to create an elevation profile and understand the total elevation gains/losses seen for each route in the system (example for Fillmore Tripper in Figure 11). Additionally, the average and maximum grades for each route were similarly determined using these elevation profiles, which were used as the inputs for the topography analysis.

Figure 11: Elevation profile example (Fillmore Tripper)

Source: Google Earth

3.1.5.1 Effects of Topography on Fuel Efficiency

We used a literature review to determine how average grades and maximum grades could affect the fuel efficiency and vehicle performance of BEBs and FCEBs. While the average grade across the entire route was used to determine the penalty on fuel efficiency, individual sections of routes that displayed significant changes in elevation in a short distance were also analyzed since this could have a outsized effect on vehicle performance. Data collection from real world operations provided the corrleation between average grade and penalties to the fuel efficiency (See Appendix B – Topography Impacts – Correlation Between Average Grade and Fuel Efficiency). A penalty factor for each route was then applied to the calculated route-level fuel efficiencies to account for topography.

Table 7 shows that, based on primary driving cycles, energy use per mile increases by 7.8% and 7.0% for BEB and FCEB cutaways (respectively) when accounting for the effects of the topography unique to the service area of VCTC. For motorcoaches, modeling primary driving cycles at high passenger loads shows that energy use per mile increases by 8.6% and 11.3% after accounting for topography.

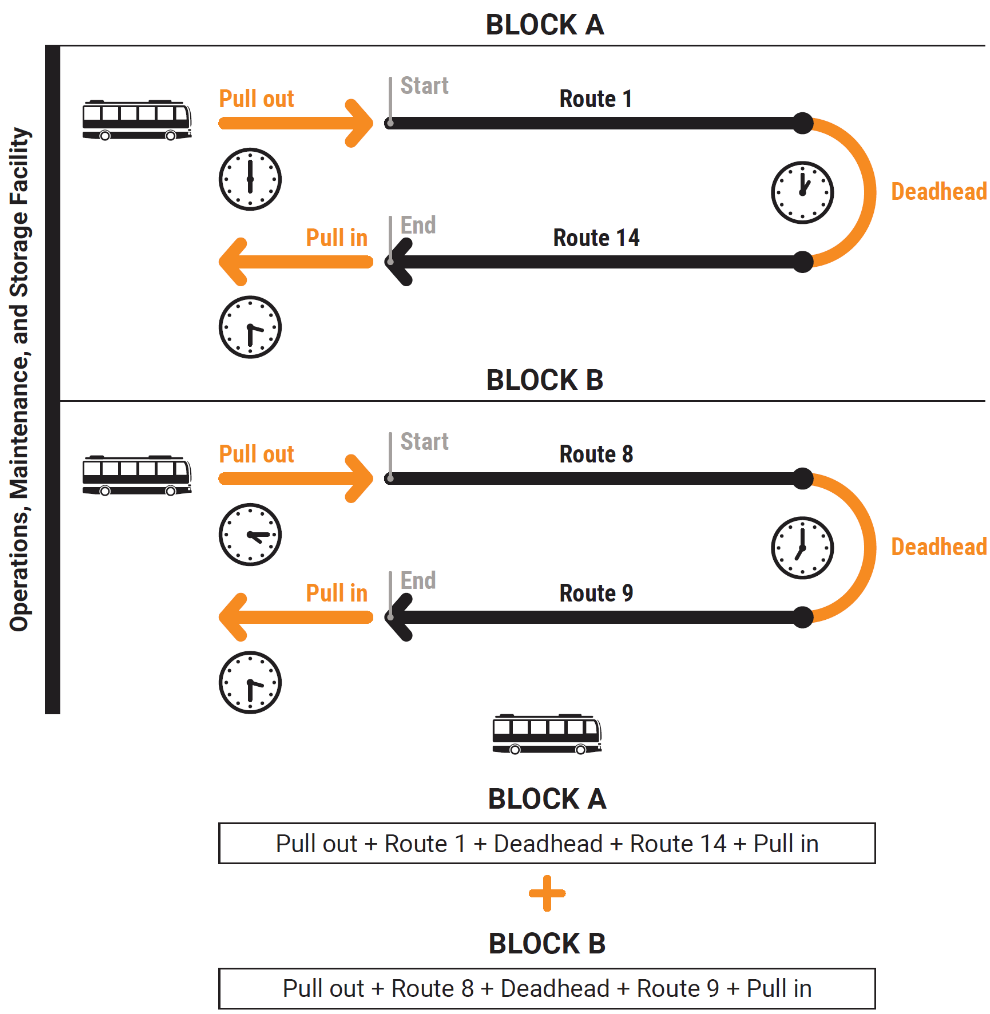
Table 7: Average change in fuel efficiency due to topography (high passenger load)

		Average Fuel Efficiency (no topography, primary cycle)	Average Fuel Efficiency with topography	Average Change
BEB	**VE (cutaway)**	1.16 kWh/mi	1.25 kWh/mi	-7.8%
	Intercity (motorcoach)	2.10 kWh/mi	2.28 kWh/mi	-8.6%
FCEB	**VE (cutaway)**	14.67 mi/kg	13.65 mi/kg	-7.0%
	Intercity (motorcoach)	7.91 mi/kg	7.02 mi/kg	-11.3%

3.2 MODELING PROCESS

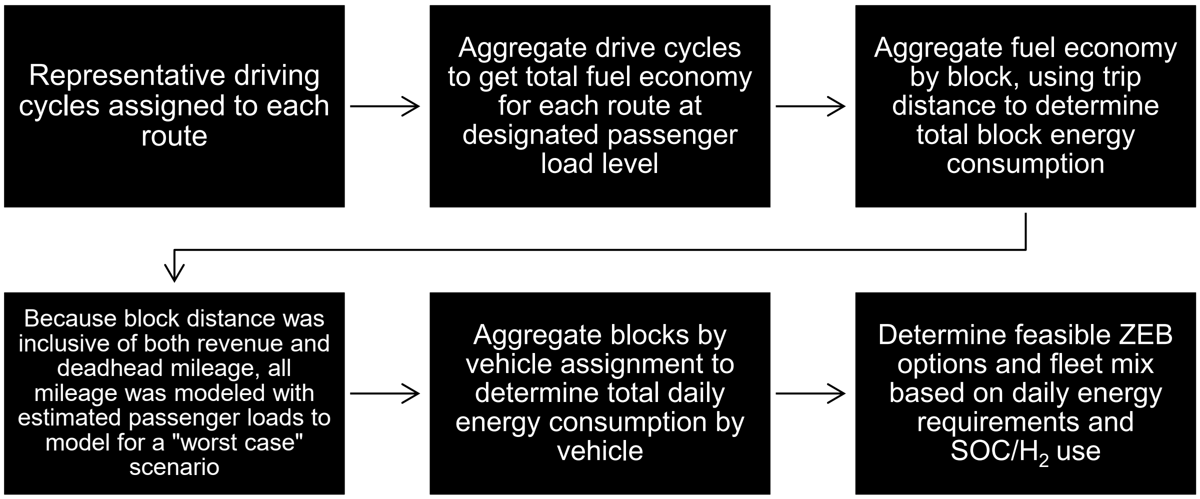
Using the inputs above, the first step in modeling Intercity and Valley Express services is obtaining route-level fuel economy and energy use for the BEBs and FCEBs using the driving cycles assigned to each route. However, we cannot stop at route-level modeling as this does not represent what a vehicle does in a day due to interlining, deadheading, etc. The graphic in Figure 12 demonstrates a hypothetical relationship between routes, deadheading, blocks, and vehicle assignments.

Figure 12: Relationship between routes, blocks, and vehicle assignments



The process of modeling a route and then assigning fuel economies to vehicle-level assignments is outlined in Figure 13.

Figure 13: ZEBDecide energy modeling process



After the route-level modeling is completed, fuel economies are then aggregated by block using the trip distance to determine total energy consumption for each block. Finally, to understand the fuel economy and total daily energy consumption of each vehicle operated on a representative service day, blocks are aggregated at the vehicle level, so that vehicles that are assigned multiple blocks throughout a day are modeled appropriately.

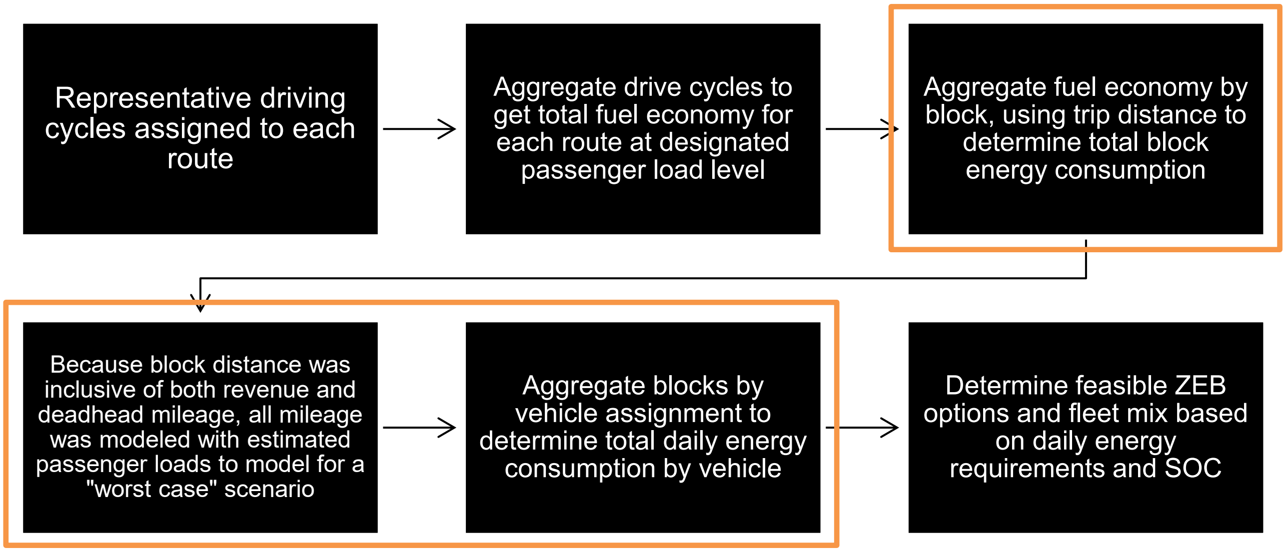
The results of the modeling provide insight into:

- Fuel economy and energy requirements
- Operating range
- The feasibility of different ZEB technologies. For BEBs, this is determined through state of charge (SOC); the vehicle assignment can be successfully completed with a BEB if it can complete its scheduled service with at least 20% battery SOC. For FCEBs, if a bus consumes less than 90% of its tank capacity, the vehicle assignment is counted as successful.

4.0 MODELING RESULTS

Following the assignment of driving cycles to routes and aggregating these to determine the total fuel economy for each route at different passenger loads, the modeling moves to the next stages which are highlighted in orange in Figure 14.

Figure 14: ZEBDecide block- and vehicle-level modeling steps



These steps define 1) the energy consumption at the block level, and 2) the energy consumption for each vehicle assignment. The modeling results for these two steps of the process are presented in the sections below, and they are categorized per service type, vehicle type, and technology type.

4.1 INTERCITY

The overall energy or fuel demand per block was obtained by aggregating the fuel consumption from each trip according to the route-level results. The criteria to deem if a block can be successfully served by a BEB is if the SOC of the battery is above 20% after completing all the trips in a block[14], and for FCEBs, the criterion for success is whether a bus consumes less than 90% of its tank capacity.

4.1.1 BE Motorcoaches

Block- and vehicle-level modeling results are shown for 525-kWh BEB motorcoaches (Figure 15). High passenger loads represent 75% seated capacity, while low passenger loads represent 25% seated capacity.

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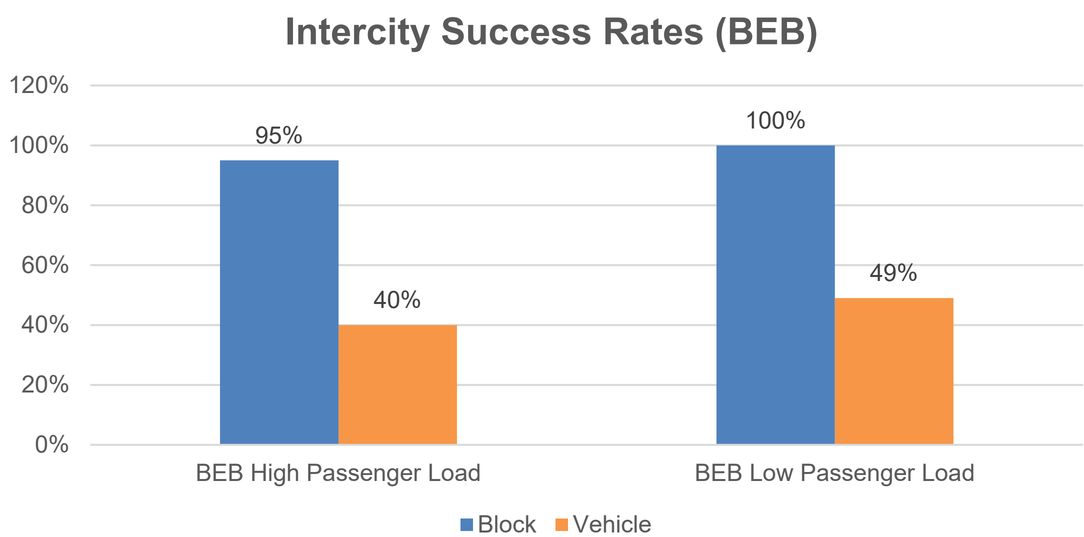
[14] OEMs recommend that a BEB charge only to 90% of its total battery capacity and not drop below 10% state of charge (SOC) to preserve battery life; dipping below 10% can void the battery warranty.

Figure 15: Intercity BEB block and vehicle success rate



These results in Figure 15 indicate that while almost all blocks are successfully modeled as BEBs even when assuming high passenger loads, fewer than half of vehicles can successfully complete their daily assignments on a single charge. In other words, since vehicles are assigned multiple blocks, the totality of the vehicle mileage exceeds the operating limit of the BEBs modeled.

Table 8 summarizes the average fuel efficiency and range for the BE motorcoach under the Intercity operating conditions.

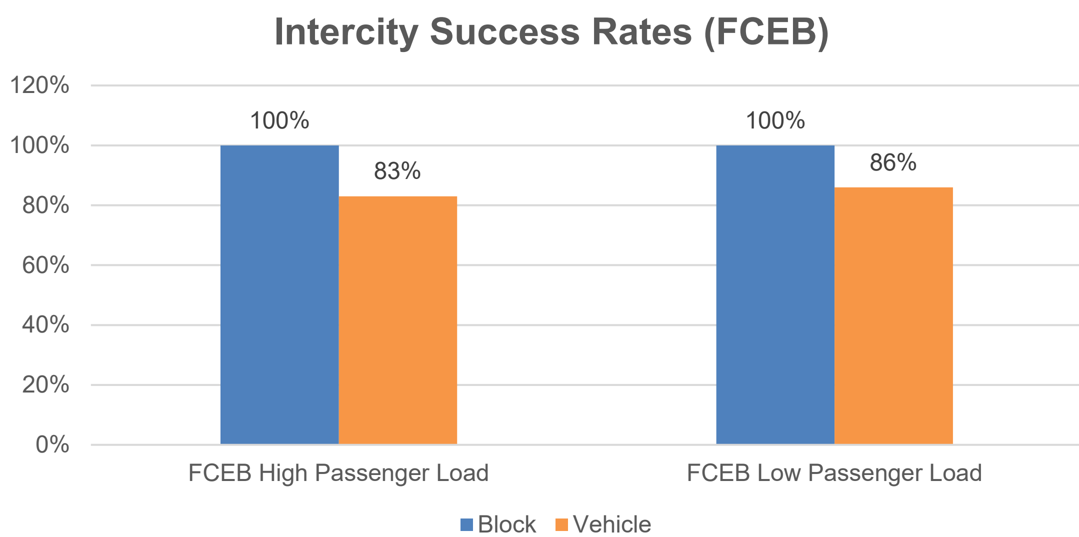
Table 8: Average fuel efficiency for Intercity BEB modeling results

Vehicle type	Average fuel efficiency (kWh/mi)	Est. max range (mi)
45-ft BE motorcoach	2.11 – 2.23	190 – 200

4.1.2 FCE Motorcoaches

Next, Intercity service was modeled with hypothetical hydrogen FCE motorcoaches equipped with 37.5-kg tanks. Figure 16 shows both the block-level and vehicle assignment-level results for FCEBs.

Figure 16: Intercity FCEB block and vehicle success rate



According to the modeling, all of VCTC's Intercity blocks assignments can be successfully transitioned to hydrogen FCE motorcoaches. Eighty-three percent and 86% of vehicles can be successfully transitioned to FCE technology based on high and low passenger loads, respectively. Table 9 summarizes the average fuel efficiency and range for the FCE motorcoach. However, it is important to recall that FCE motorcoaches are not currently commercially available, and no actual real-world data exists regarding their performance.

Table 9: Average fuel efficiency for Intercity FCEB modeling results

Vehicle type	Average fuel efficiency (mi/kg)	Est. max range (mi)
34-ft FCE motorcoach	6.8 – 7.0	240 - 250

4.2 VALLEY EXPRESS

As with Intercity services, Valley Express services were first modeled at the block level and then aggregated at the vehicle level to represent all the trips that a vehicle completed on the sample day. The criteria for success for Valley Express services are the same as for Intercity services—completion of daily assignment with at least 20% SOC (BE vehicles) or no more than 90% tank capacity consumed (FCE vehicles).

4.2.1 BE Cutaways

Figure 17 shows that 90% of Valley Express blocks can be successfully electrified, but after sorting the blocks into vehicles, it was determined that only 44% of vehicles could be electrified.

Figure 17: Valley Express BE block and vehicle success rate

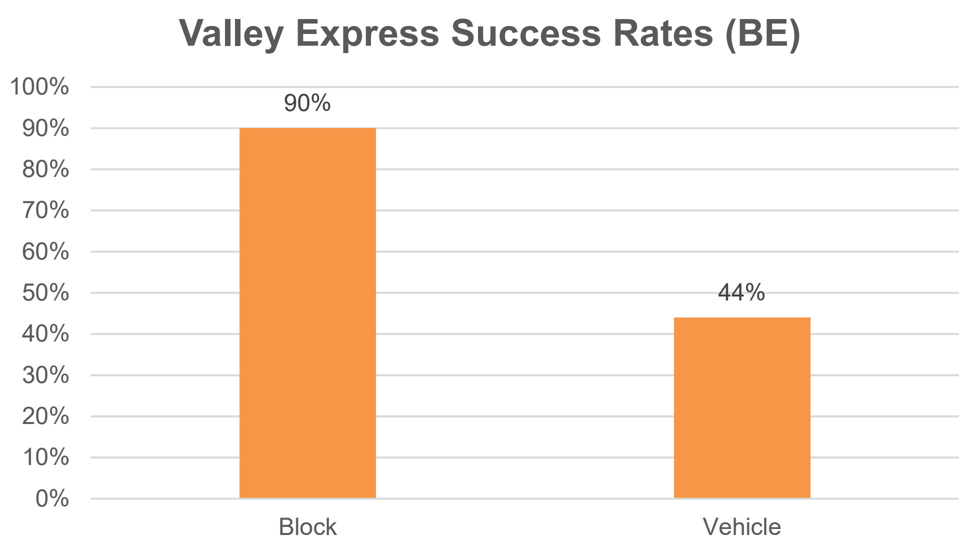


Table 10 summarizes the average fuel efficiency and expected maximum range for BE cutaways.

Table 10: Average fuel efficiency for Valley Express BE modeling results

Vehicle type	Average fuel efficiency (kWh/mi)	Est. max range (mi)
BE cutaway	1.19	90

4.2.2 FCE Cutaways

Figure 18 shows that 100% of Valley Express blocks and 78% of vehicles can be successfully transitioned to hydrogen fuel with cutaways that have 13.5-kg tanks. Table 11 summarizes the average fuel efficiency and expected maximum range for FCE cutaways.

Figure 18: Valley Express FCE block and vehicle success rate

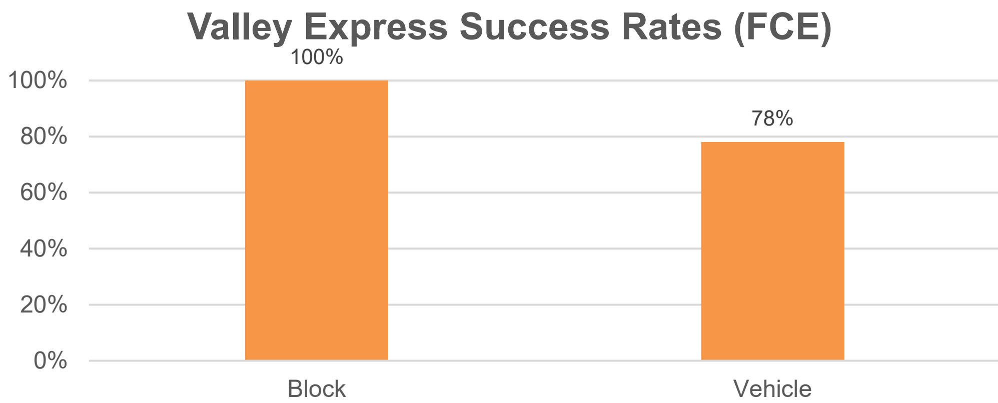


Table 11: Average fuel efficiency for Valley Express FCE modeling results

Vehicle type	Average fuel efficiency (mi/kg)	Est. max range (mi)
FCE cutaway	14	160

The daily maximum mileage for hydrogen cutaways operating Valley Express service is 160 miles with an average fuel efficiency of 14 mi/kg.

4.3 SUMMARY AND TAKEAWAYS

In summary, the modeling results have the following major implications:

- Intercity service modeling results show that difficulties arise when modeling either BEB or FCEB options based on VCTC's operations. This is due to the fact that while block-level modeling demonstrates almost universal success (for either BE or FCE vehicles), vehicle-level results are less so. Forty percent to 49% of Intercity vehicles can be successfully transitioned to BE technology, while 83% to 86% of vehicles can be transitioned to FCE technology.
- Valley Express results show similar disparities between technologies with 44% and 78% successfully modeled for BE and FCE cutaways, respectively.
- The results imply that VCTC cannot successfully transition their service to ZEBs (as the technologies currently exist) in a 1:1 manner and may need to explore other strategies such as reblocking or growing the fleet size.
- Notably, while modeling success rates for hydrogen vehicles were more greater than BE vehicles, hydrogen motorcoaches (for Intercity) and cutaways (for Valley Express) are not yet commercially available.

Based on these modeling results, potential fleet concepts have been developed for each service type and are detailed in the following sections.

5.0 FLEET CONCEPTS AND ASSESSMENT

This section first outlines the development of potential ZEB fleet concepts, followed by the specification of two fleet concepts for the Valley Express and three fleet concepts for Intercity based on the modeling and analysis in preceding sections. For Intercity fleet concepts, we conducted a strengths, weaknesses, opportunities, and challenges (SWOC) analysis for each of the three fleet concepts. The two concepts that emerged as the most viable according to the SWOC analysis underwent a multicriteria analysis to compare various quantitative and qualitative aspects of the fleet concepts in more detail to ultimately arrive at a recommended fleet concept.

Based on the modeling results, VCTC could decide to proceed a few different ways in terms of fleet composition for ZEB transition. Given that the fleet, operations, and service delivery of the Intercity and Valley Express are essentially completely separate, the considerations and rationales that inform fleet concept decisions are discussed separately below.

5.1 INTERCITY

Three preliminary fleet concepts were developed for Intercity service: an all-BEB fleet, all-FCEB fleet, and a mixed fleet comprised of both BEBs and FCEBs.

Regardless of technology type, one of the main challenges for VCTC is that they do not own the facility that houses the fleet. Investing in charging or fueling infrastructure at a leased facility is not a viable option and presents risks if VCTC chooses a different contractor with a different maintenance facility in the future. As such, VCTC will need to explore partnerships with regional transit partners or other agencies to share charging or fueling infrastructure. A number of different opportunities exist for coordinated offsite fueling/recharging:

- Gold Coast Transit District (GCTD), the local transit service provider for western Ventura County, has committed to transitioning to a hydrogen fleet and will start construction (in 2023) on an onsite hydrogen fueling station at their facility in Oxnard. During the planning phases, extra hydrogen supply and an additional fueling lane were incorporated so that Intercity motorcoaches can also fuel at the GCTD facility. VCTC would need to account for the additional non-revenue mileage of driving to and from the facility in Oxnard, as well as work out any necessary cost sharing agreement and any other logistics with GCTD to share the hydrogen fueling infrastructure.
- Through a recent Transit and Intercity Rail Capital Program (TIRCP) grant submitted by SBCAG, VCTC will soon be receiving five BE motorcoaches. It is anticipated that these coaches will operate on the Coastal Express service to and from Santa Barbara County, and will charge at a charging facility in Goleta.

- The City of Camarillo is exploring installing charging infrastructure at their Metrolink station, which VCTC could utilize.
- Generally speaking, if BEBs are deployed for Intercity service, VCTC will need to identify feasible and strategic locations for charging which would need to present several criteria, such as:
  - Being located nearby route terminals or end points.
  - Being located at a site or facility that would be available to VCTC for a long-term time period.

These three fleet concepts, including high-level charging/fueling strategies and other considerations, are summarized in Table 12.

Table 12: Preliminary Intercity fleet concepts

	BEB Concept	FCEB Concept	Mixed Fleet Concept
Fleet Concept[15]	37 BEBs	35 FCEBs	17 BEBs 18 FCEBs
Charging/ Fueling	Offsite charging at Goleta and Camarillo+ overnight charging	Refueling at Gold Coast Transit District (GCTD)	Refueling at GCTD + overnight charging
Considerations	Requires coordination for off-site charging at Goleta and Camarillo. Charging infrastructure required at the Camarillo Metrolink station for 37 BEBs, even if it's not where vehicles are parked overnight. Potential participation with SCE Charge Ready Program at the Metrolink station if a portion of the facility can be	Additional non-revenue mileage for off-site refueling at GCTD. Coordination with GCTD for refueling logistics, payment, etc. Considerations for the additional labor costs and personnel required for off-site fueling at GCTD	Requires coordination for off-site charging at Goleta. Charging infrastructure required at the Camarillo Metrolink station for 17 BEBs, even if it's not where vehicles are parked overnight. Potential participation with SCE Charge Ready Program at the Metrolink station if a portion of the facility can be

[15] Number of vehicles based on active fleet, not total fleet size.

	BEB Concept	FCEB Concept	Mixed Fleet Concept
	secured to store the buses overnight. Investment at a facility that VCTC doesn't own is not feasible Requires increasing active fleet size by two vehicles for service provided to Fillmore since no opportunities for off-site refueling during service are available	Some vehicles might require midday refueling.	secured to store the buses overnight. Additional non-revenue mileage for off-site storage. Coordination with GCTD for hydrogen refueling logistics, payment, etc. Considerations for the additional labor costs and personnel required for off-site fueling at GCTD Some vehicles might require midday refueling. Requires deployment of BEBs on shortest blocks/routes and FCEBs on longer blocks/routes.

Each of these three preliminary concepts then underwent a SWOC analysis to better understand their viability, presented in Table 13, Table 14, and Table 15.

Table 13: SWOC analysis: BEB concept

Strengths Existing technology – more readily available than FCEBs. In use by other transit agencies and VCTC will use them soon. Potentially less expensive per bus cost compared to hydrogen.	**Opportunities** Partnerships with regional agencies for shared charging infrastructure.
Weaknesses	**Challenges**

Shorter range compared to hydrogen. Charging takes longer compared to hydrogen refueling. Requires installation of charging infrastructure at facility not owned by VCTC. Potential need for reblocking to accommodate BEB ranges. Need to grow fleet size by two additional vehicles.	Complex coordination with partners for charging. Potential issues with electrical grid reliability.

Table 14: SWOT analysis: FCEB concept

Strengths Longer range than BEBs. Shorter refueling time compared to BEBs. Reduces need to re-block/adjust scheduling and dispatching; more business-as-usual approach to operations. Refueling process is similar to diesel or CNG refueling.	**Opportunities** Opportunity to fuel at GCTD. Hydrogen is becoming a more common technology choice for transit agencies (GCTD, Foothill, SunLine, OCTA, RTA, Pasadena Transit).
Weaknesses Technology does not exist/market ready in vehicle type required. Likely more expensive per-bus cost compared to BEBs.	**Challenges** Hydrogen technology may not be available when VCTC needs to begin procuring hydrogen motorcoaches.

Table 15: SWOT analysis: Mixed fleet concept

Strengths BEB technology exists and more readily available than FCEBs.	**Opportunities** Opportunity to fuel FCEBs at GCTD.

Can deploy BEBs on shorter routes/blocks and FCEBs on longer routes/blocks. VCTC can first procure BEBs and wait to procure FCEBs until the technology is available.	Opportunity to partner with other agencies in the region for BEB charging infrastructure. Would leverage BEBs that are on order.
Weaknesses Hydrogen coaches currently do not exist/market ready. Requires careful planning/operations to ensure correct technology type is dispatched on correct blocks/routes. Require use of multiple technology types and need to train workforce on two different types of technology.	**Challenges** Hydrogen technology may not be available when VCTC needs to begin procuring hydrogen vehicles. Complex coordination with partners for charging. Potential issues with electrical grid reliability.

Based on this SWOT analysis, the BEB fleet concept was not considered further as this is the least viable option for VCTC to move forward with, and the weaknesses and challenges outweigh strengths and opportunities compared to the other fleet concepts. The two remaining fleet concepts (**Fleet Concept A: FCEB fleet** and **Fleet Concept B: Mixed fleet**) were assessed through a multicriteria analysis to gain a more detailed understanding of the trade-offs between the two fleet concepts.

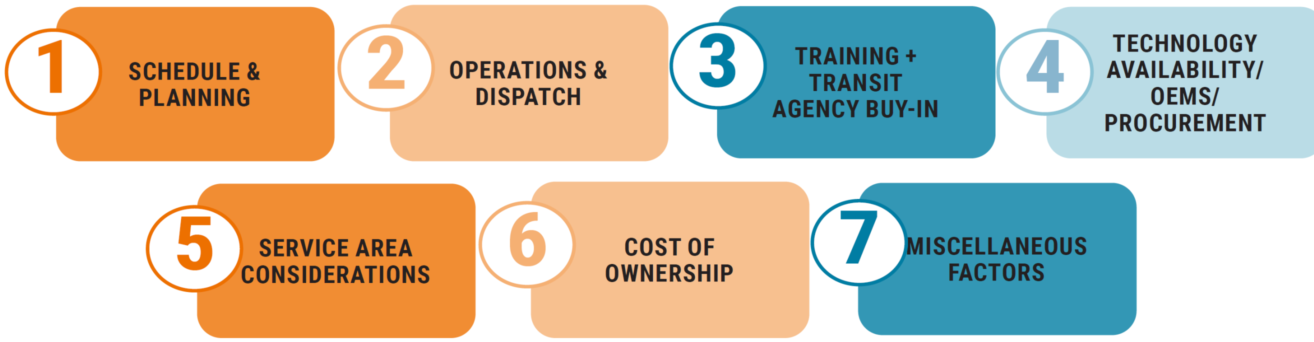
5.1.1 Multicriteria Analysis and Evaluation

Bus modeling and route simulation provides one important input into the recommendation of a preferred Intercity ZEB fleet concept—the modeling helps understand the feasibility of different technologies. In certain instances, combinations ZEB technologies could be feasibly implemented albeit with different considerations (which is the case for VCTC), while in other instances, one technology choice may not be feasible or may be an improper fit for a transit agency due to a range of reasons.

As such, there are other qualitative and quantitative considerations for Intercity service. Some of these have been alluded to throughout this report, such as the complexity of VCTC not owning their facilities, the complexity of operating multiple ZE technologies, the lack of ZE equivalents for VCTC's vehicle types, and so on.

Figure 18 is a schematic of the different criteria considered in the multicriteria analysis to evaluate the trade-offs of the two Intercity ZEB fleet concepts.

Figure 18: Criteria for the multicriteria analysis of ZEB fleet concepts



- **Scheduling and planning** considers how range limitations, fleet variants, and other characteristics of the fleet could impact scheduling and planning of VCTC's service.
- **Operations and dispatch** considers the degree of complexity and flexibility provided by the fleet concepts to operations (including maintenance) and dispatching.
- **Training and agency-wide buy-in** considers the scale and complexity of required agencywide training to familiarize the agency with the chosen ZE technology.
- **Technology availability/OEMs/Procurement** considers how complex procurement will be under each fleet concept and how current availability of vehicles under each technology option will impact the feasibility of transitioning.
- **Agency/Service Area-specific considerations** include concerns and factors that are unique to VCTC and the region in which it operates.
- **Cost of ownership** evaluates, at a high-level, the capital cost estimates (vehicle purchases and charging/fueling infrastructure) of each fleet for preliminary comparative purposes.

Table 16 presents a comparison between the two fleet configurations for different trade-off criteria. It should be noted that any of the arrangements discussed throughout would also need to accommodate current operations—in other words, at least for a time, Intercity would potentially operate up to three technologies (diesel, BE, and FCE).

In Table 16:

- 1 star indicates a Fair fit for VCTC
- 2 stars indicate a Good fit for VCTC
- 3 stars indicate a Best fit for VCTC

Table 16: Trade-offs between Intercity Fleet Concepts A and B

Trade-off/criteria	Fleet Concept A (FCEB Fleet)	Fleet Concept B (Mixed Fleet)	Notes/Comments

Scheduling and planning	• Requires scheduling for FCE motorcoach with a maximum range of ~240 miles (37.5 kg tank)
	• Only one vehicle type is required.
	• Vehicles can be dispatched for any block, offering more scheduling flexibility.
	• FCEBs offer greatest flexibility for detours and other unplanned/planned service changes and road calls/changeouts
	• Smaller battery packs in FCEBs have less degradation.
	★★★
		• Requires scheduling for:
		  ○ BE motorcoach with a maximum range of ~190 miles (525 kWh battery) and
		  ○ FCE motorcoach with a maximum range of ~240 miles (37.5 kg tank)
		• Requires scheduling changes; buses can only be dispatched on certain blocks due to range requirements. Less scheduling flexibility to ensure buses with longer ranges are scheduled to longer blocks.
		• Significant BEB battery degradation presents uncertainty in service reliability (range) as vehicles age.
		★★☆
			• Fleet Concept A simplifies scheduling and planning by having the fewest variants of bus types; more flexibility in dispatching buses to blocks due to longer range and minimizes reblocking.
			• Fleet Concept B presents more scheduling and planning constraints with two different fleet types for the bus fleet.

Operations and dispatching	• Dispatch will have flexibility to assign any vehicle to blocks because of similar ranges across vehicles. This will help to evenly distribute the mileage per vehicle among the fleet. • Refueling FCEBs takes a much shorter time compared to BEBs (around 10 minutes/FCEB based on peer agency experience). • Additional non-revenue mileage for off-site refueling. • Coordination with GCTD for refueling window.	• Dispatch and maintenance will need to consider and manage the two fuel types to ensure that vehicles are dispatched as scheduled and assigned to the correct blocks. • Parking and charging times for BEBs need to be closely monitored to ensure a full battery and free dispatching for the next service day. • Recharging BEBs can take between 2-6 hours and will likely require swapping dispenser connections to buses overnight or smart charging software with remote smart managing, depending on the final charging coordination strategy. • The preventative maintenance cycles will need to be closely monitored for each vehicle type since a portion of the fleet may accumulate more miles per day from being assigned to the longer blocks, resulting in more preventive maintenance	• Having the fewest variants or types of bus technologies is preferable to simplify dispatching.

Trade-off/criteria	Fleet Concept A (FCEB Fleet)	Fleet Concept B (Mixed Fleet)	Notes/Comments
	★★☆	• Additional non-revenue mileage for off-site refueling • Coordination with GCTD for refueling window ★☆☆	
Training and agency-wide adoption	• Requires training for operators, mechanics, schedulers, etc. for *one* vehicle type • Considerations are needed to understand personnel types (operators, service line staff, etc.) capable/permitted to fuel hydrogen vehicles at GCTD ★★★	• Requires training for operators, mechanics, scheduler, etc. for *two* technology types. • Considerations are needed to understand personnel types (operators, service line staff, etc.) capable/permitted to fuel hydrogen vehicles at GCTD • Training for staff to use off-site charging equipment ★★☆	
Technology availability/OEMs/ procurement	• No FCE motorcoach OEMs at present • Requires one set of spare parts, tools, etc. ★☆☆	• Few BE motorcoach OEMs at present, and still difficult to procure • No FCE motorcoach OEMs at present • Requires sets of spare parts, tools, etc. for both BE and FCE motorcoaches. ★★☆	
Infrastructure	• Could require investment in facilities not owned by VCTC for hydrogen code compliance • Requires significant maintenance building upgrades for hydrogen vehicles. • Requires changes to maintenance bays and tooling for FCE technology. ★☆☆	• Likely requires investment in facilities not owned by VCTC for hydrogen code compliance • Requires changes to maintenance bays and tooling for BEB and FCEBs technology. • Potential participation with SCE Charge Ready Program if 10+yrs lease is available at the Camarillo Metrolink station ★☆☆	

Trade-off/criteria	Fleet Concept A (FCEB Fleet)	Fleet Concept B (Mixed Fleet)	Notes/Comments
Agency-specific considerations	• Requires coordination with one agency ★★☆	• Requires coordination with multiple agencies ★☆☆	

Capital cost considerations	• Estimated cost – ~$51 million
	  ○ 35 FCE coaches x $1.47M = $51M
	• Significantly cheaper than if VCTC needed to construct its own hydrogen fueling facility
	★★☆
		• Estimated cost – ~$49 million
		  ○ 17 BE coaches x $1.2M = $21.3M
		  ○ 18 FCE coaches x $1.47M = $26.4M
		  ○ 8 chargers (150 kW) = $1.36M
		• Does not include all the costs of BE installation, potentially buying land, etc.
		★★½
			• Cost considerations are high-level and only consider capital costs.

Other	• Deviations from modeled fuel efficiency of FCEBs can be mitigated by additional refueling during the day (quicker and less disruptive to operations than midday charging). • Per-bus effort and cost decreases as fleet size increases (scalability). • Resiliency will depend on GCTD's level of back-up for hydrogen fueling ★★☆	• Heavy investment in power resiliency needed to support operations in case of outages • Deviations from modeled fuel efficiency of BEBs due to real-world operations and battery degradation can be disruptive and could require adding additional buses to complete service. • Per-bus effort and cost increases as fleet size increases. ★★☆	• Deviations from modeled fuel efficiency can be mitigated more easily for FCEBs than BEBs (shorter time required for refueling).
Overall best fit for VCTC	★★☆	★☆☆	

This trade-off analysis reveals that significant challenges emerge with either fleet concept. While Fleet Concept B costs slightly less than Fleet Concept A, Fleet Concept A (all-FCEBs) is overall a better fit for Intercity's service profile. While hydrogen vehicles are projected to be more expensive on a per-bus basis compared to BE motorcoaches, it is significantly less expensive than a scenario where VCTC needed to construct its own hydrogen fueling station. Further, fueling at GCTD is less complex than working with multiple different partners to implement BEB charging throughout the Intercity service area. Finally, FCEB operations and fueling will be much more similar to current-day operations, and VCTC will not have to ensure that the correct technology type is deployed on the correct blocks. A hydrogen fleet also has the potential to be more resilient during emergency situations and natural disasters, whereas a BEB fleet might suffer from grid unreliability. It must be noted that Fleet Concept A would still introduce BEBs as part of the initial ZEB fleet transition, since VCTC will be taking possession of BEB motorcoaches in early 2023.

However, there is still a significant risk with either scenario in that hydrogen motorcoaches may not be commercially available and Altoona-tested by the time VCTC needs to start acquiring them. Thus, Fleet Concept B should still be considered as a backup plan, so that VCTC can begin to acquire BE motorcoaches while waiting for the hydrogen technology to mature and a vehicle to come onto the market. This also lets VCTC take advantage of current funding programs for ZEBs, both for vehicle purchases and through potential participation in the SCE Charge Ready Transport Program.

5.2 VALLEY EXPRESS

Two fleet concepts were explored for the Valley Express service: a BEB concept and FCEB concept (Table 17).

Table 17: Preliminary Valley Express fleet concepts

	BEB Concept	FCEB Concept
Fleet Concept[16]	9 BEBs	Not considered as a viable fleet concept because: • Refueling at Gold Coast Transit District (GCTD), which is 10+ miles away from the current Valley Express facility in Santa Paula.
Charging/ Fueling	Requires installation of charging infrastructure at the Santa Paula facility (or somewhere in the Heritage Valley), specifically five chargers with dual dispensers.	

[16] Number of vehicles based on active fleet, not total fleet size.

	BEB Concept	FCEB Concept
Considerations	Potential participation with SCE Charge Ready Program. Requires increasing active fleet size by four vehicles. Requires collaboration with different partners to install and share charging infrastructure, since VCTC does not own any facilities	• No public hydrogen station options for cutaways in or near the Valley Express service area. • Capital investment for a small hydrogen fleet is not cost effective. • Hydrogen cutaways currently do not exist.

Shorter operating ranges of BE cutaways compared to FCE cutaways means that an all-BE fleet concept being difficult to implement; if it is assumed that operating ranges will eventually improve as technology (namely batteries) matures, BE vehicles could replace current vehicles at a 1:1 ratio. As the technology currently exists, VCTC would need to acquire an additional four BE cutaways to provide the same amount of service that they do today. In addition to the increased capital cost of purchasing more vehicles, this has further financial considerations as more operators could be required to provide the same amount of service.

Charging or fueling will be a challenge for any ZEB fleet operated for Valley Express service. Under the BE fleet concept, VCTC could install charging infrastructure at their current contractor facility, but investing in a facility that VCTC does not own is not an attractive option for VCTC and not a viable approach. VCTC could also explore buying land for a dedicated, VCTC-owned maintenance facility. This is not a preferred option because VCTC is only administering the Valley Express service on behalf of the local municipalities.

Alternatively, VCTC could require charging infrastructure from potential O&M contractors in future operations and maintenance contracts, but this could increase costs to provide service and introduce risks to future service provision.

VCTC could also explore strategic partnerships with municipalities or public works departments in the Santa Paula/Fillmore/Piru area for shared charging infrastructure. Considerations for this option include finding a location where vehicles can securely and safely charge overnight, as cutaways are currently not equipped with fast-charging capabilities and would require charging over several hours. VCTC can also explore partnering with other public agencies and/or private actors for charging opportunities, but the key constraint is that any charging that requires the vehicles being left unsupervised for any significant amount of time will require secure storage as per federal regulations for vehicles purchased with federal grants.

Service modeled with hypothetical hydrogen cutaways revealed that hydrogen technology could theoretically successful deliver over 80% of Valley Express service. However, the hydrogen cutaway market is in its infancy and there are currently no Altoona-tested hydrogen cutaways available on the market; the only model Stantec is aware of is a retrofit of a gasoline cutaway. And since investing in a costly hydrogen fueling station is cost prohibitive for a small fleet (and investing in a facility not owned by VCTC isn't viable), fueling would need to be completed offsite; there are no hydrogen fueling stations nearby and the distance to fuel at GCTD's eventual station would introduce significant mileage (over 20 miles for a round trip between Santa Paula and Oxnard). For these reasons, a full hydrogen fleet for Valley Express service is not currently feasible.

6.0 FLEET CONCEPT RECOMMENDATIONS

The recommendations that follow are based on the outlook of the ZEB market and assumptions about the short-term developments in ZEB technologies, as well as modeling results which are based on the ZE technologies as they currently exist. Furthermore, the modeling results and fleet concepts, including the trade-offs and SWOC analysis were workshopped with VCTC to consider staff expertise and insights. Furthermore, CARB acknowledges that the ICT ZEB rollout plan submitted by every agency is a living document intended as a guideline or framework for ZEB adoption, and not a set-in-stone approach that should evolve as technology matures and an agency's fleet outlook changes over time.

Due to the vehicle types VCTC operates and the fact that VCTC does not own either of their facilities, VCTC is in a unique position compared to other transit agencies subject to the ICT regulation. VCTC is actively exploring innovative options, such as regional partnerships for charging/fueling. If the technology of vehicles does not improve enough, or if vehicles required to reliably operate Intercity and Valley Express services are not available by the time VCTC needs to start acquiring them, VCTC could explore an exemption based on logistical/feasibility issues, based on subsection 2023.4 of ICT regulations[17]. The exemption would require detailed documentation and information for the review of CARB and would be required for the year that VCTC is requesting an exemption from purchasing its planned apportionment of ZEBs.

Based on the information presented throughout this report, the following ZE fleets are recommended for VCTC's services:

- **Intercity**: proceed with Fleet Concept A, an all-FCEB fleet. However, VCTC should also plan for a mixed fleet as a backup plan, so that VCTC can begin to acquire BE motorcoaches while waiting for the hydrogen technology to mature and a vehicle to come onto the market. This also lets VCTC take advantage of current funding programs for ZEBs, both for vehicle purchases and through potential participation in the SCE Charge Ready Program. Since VCTC will soon take possession of five BEB motorcoaches, VCTC can use these five vehicles to offset the purchase of future ZEBs, depending on its fleet replacement schedule.
- **Valley Express**: plan for an all-BEB fleet, acknowledging that the technology and ranges will need to improve before VCTC can begin to reliably operate the service in a cost-effective manner that does

[17] ICT Clean Final Reg. Order (ca.gov)

not entail growing the fleet size. VCTC can explore opportunities with local municipalities for shared charging infrastructure.

7.0 SUMMARY AND NEXT STEPS

Presented in this report is the methodology used to develop different ZEB fleet scenarios to fit VCTC's service design and delivery, along with initial fleet concepts and a review of the trade-offs of each concept.

VCTC faces unique challenges in its transition to a ZEB fleet. Nonetheless, after assessing each fleet concept and understanding the benefits and constraints of each by examining factors such as cost of ownership, facility impacts and fueling considerations, training considerations, and operational considerations, it is the professional recommendation of Stantec to proceed with Fleet Concept A (an all-FCEB fleet) for Intercity, and for VCTC to adopt an all-BEB fleet for Valley Express. The ZEB plan that VCTC presents to CARB will be a living document that needs to be updated as conditions change.

Following selection and approval of a preferred fleet concept by the VCTC Board of Commissioners, Stantec will move forward to the next stage of the ZEB rollout plan process, which includes developing the Rollout Plan for submittal to CARB and detailing the needs of the preferred fleet concepts, including:

- Required facility and infrastructure modifications
- A phased fleet transition schedule to achieve a 100% ZE fleet by 2040
- Identifying staffing needs and changes and workforce training requirements
- Identifying potential funding sources
- Completing a financial analysis to understand the financial implications of the ZEB transition
- Developing the final rollout plan and implementation strategy

APPENDIX A – DRIVING CYCLE ASSIGNMENTS

Categorization of service routes to representative driving cycles

Route	Service	Assigned Primary Cycle	Assigned Secondary Cycle
Fillmore Loop	Valley Express	Medium Traffic	OCTA
Fillmore Tripper-AM Rio Vista	Valley Express	Medium Traffic	
Fillmore Tripper-PM Rio Vista	Valley Express	Medium Traffic	
Piru	Valley Express	UDDS	OCTA
Santa Paula A	Valley Express	OCTA	
Santa Paula B	Valley Express	Medium Traffic	
Santa Paula School Tripper	Valley Express	Medium Traffic	
50-Hwy 101	Intercity	Commuter	OCTA
52-Hwy 101	Intercity	Commuter	OCTA
52x-Hwy 101	Intercity	Commuter	OCTA
60-Hwy 126	Intercity	UDDS	Medium Traffic
62-Hwy 126	Intercity	UDDS	Medium Traffic
70-East County	Intercity	Commuter	OCTA
72-East County	Intercity	Commuter	OCTA
73-East County	Intercity	Commuter	OCTA
73x-East County	Intercity	Commuter	OCTA
77-Cross County Limited	Intercity	UDDS	OCTA
80-Coastal Express	Intercity	Commuter	OCTA
80c-Coastal Express	Intercity	Commuter	OCTA
80x-Coastal Express	Intercity	Commuter	OCTA
81-Coastal Express	Intercity	Commuter	OCTA
81b-Coastal Express	Intercity	Commuter	OCTA
84-Coastal Express	Intercity	Commuter	OCTA
84U-Coastal Express	Intercity	Commuter	OCTA

APPENDIX B – TOPOGRAPHY IMPACTS – CORRELATION BETWEEN AVERAGE GRADE AND FUEL EFFICIENCY

Figure 19 and Figure 20 show the correlations between average grade and fuel efficiency. Data to construct the correlations was collected from real world operations of different vehicle types at various terrain grades. Figure 19 shows the average grade observed during the data collection process and Figure 20 presents the root mean square (RMS) of the encountered grades. The RMS was used to calibrate the available road grade database with the GPS data collected from each trip. A combination of these two correlation effects was used to determine the elevation penalty for each route. These factors were used to develop fuel efficiency estimates presented in Section 3.1.5.

Figure 19: Correlation of average grade and fuel efficiency penalty on different types of vehicles

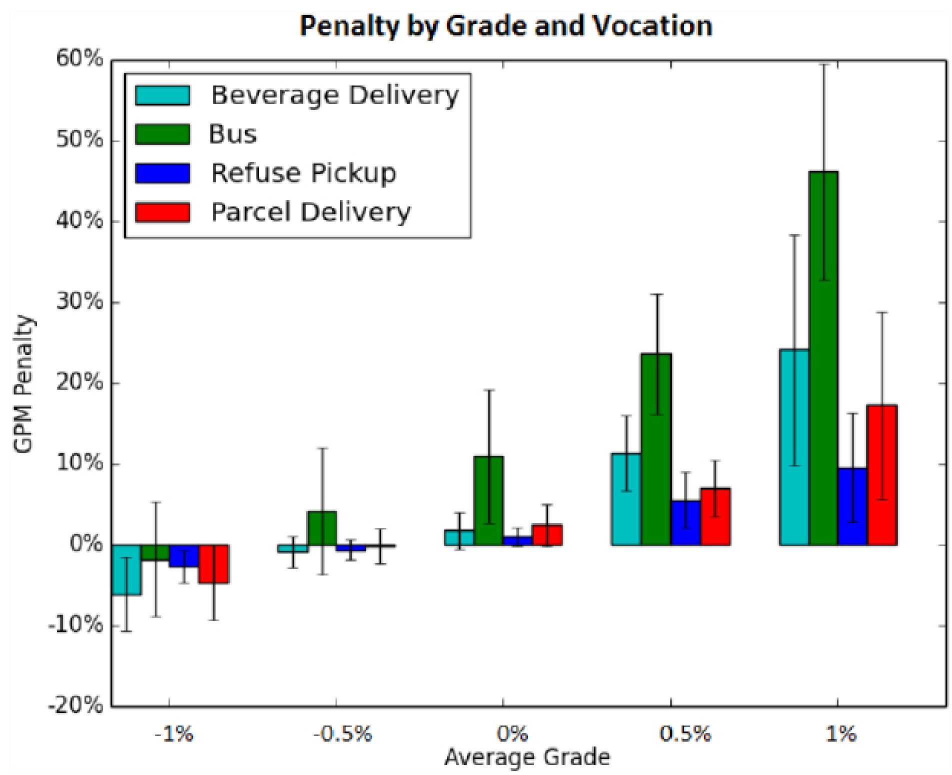
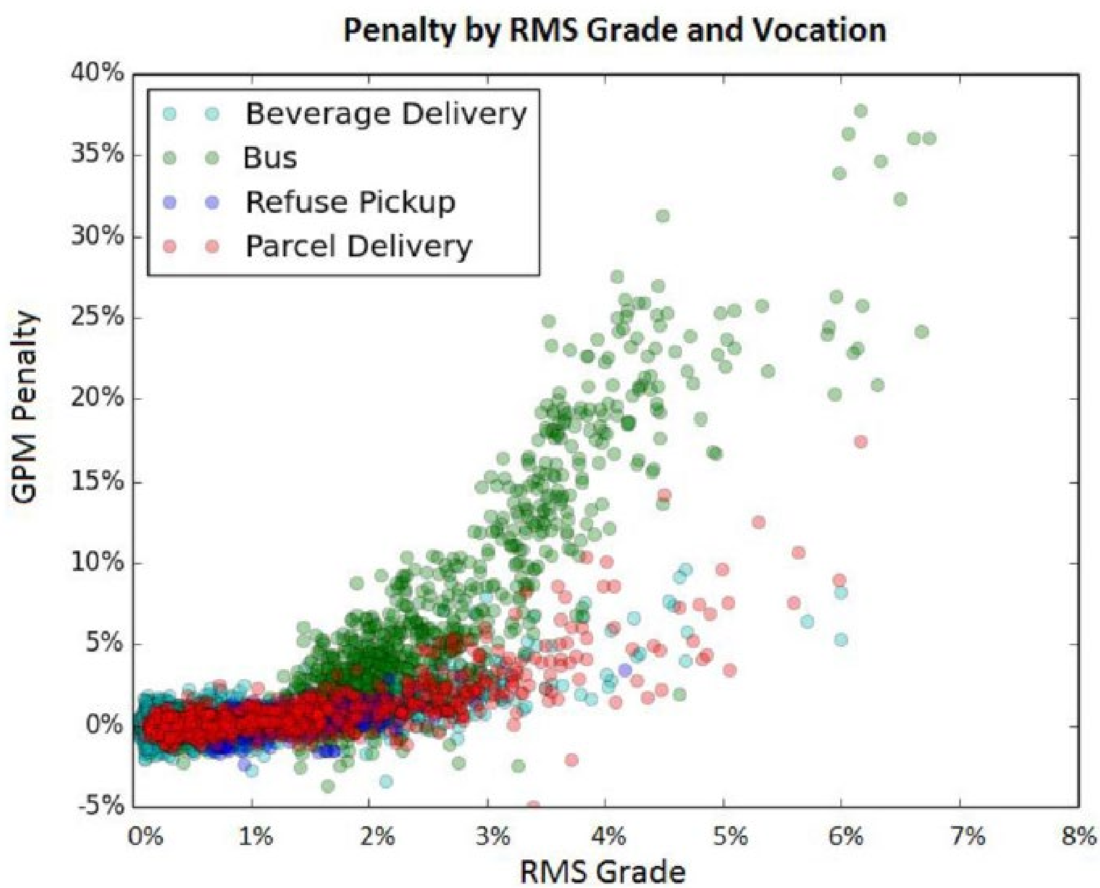


Figure 20: Correlation of RMS grade and fuel efficiency penalty on different types of vehicles[18]



[18] Lopp, S., Wood, E., and Duran, A., "Evaluating the Impact of Road Grade on Simulated Commercial Vehicle Fuel Economy Using Real-World Drive Cycles," SAE Technical Paper 2015-01-2739, 2015.