planning exercise. During scenario development, local and regional stakeholders were asked to allocate 16,500 new jobs and 28,000 new households (based on an estimated 60,000 new population).

*Residential Housing, Population, and Employment Base Year Spatial Placement*
In order to determine the spatial placement of population for the base year (2008), the consultant team used the Land Use (2005) data layer from MassGIS and adjusted municipal-level total population figures based on 2008 estimates from the U.S. Census 2000. The consultant team also used the MassGIS Land Use (2005) layer in conjunction with the Parcel-based Existing Land Use layer obtained from Cape Cod Commission to determine the spatial placement of base year employment. Similar to its approach to the population data, the consultant team used U.S. Census 2000 estimates for 2008 to adjust municipal-level total employment figures.

*Development Capacity*
In developing its preliminary scenarios (Trend, Dispersed Development, and Targeted Development), the consultant team relied on the August 2007 Zoning data layer maintained by MassGIS to conduct a regional build-out analysis for potential development capacity. The consultant team validated the MassGIS layer against local zoning maps and, in some cases, adjusted it to account for discrepancies.

*VMT and GHG Estimates*
In order to incorporate estimates of GHG reductions into scenario development, the consultant team used estimates of VMT from CCC's TransCAD transportation model. The consultant team also evaluated a statewide TransCAD model maintained by MassDOT but decided to use the CCC model based on assumptions that it was more sensitive to regional factors. The CCC's model also more closely matched the Pilot Project's base and horizon year, having been completed in 2007 and extending to 2035. Using the CCC transportation model as a baseline, the consultant team applied the 5D method developed by Ewing and Cervero[2] to estimate the impact of land use changes on VMT. The consultant team calculated the following metrics to account for each variable in the 5D analysis:

- Design: Road miles per square mile
- Density: Household units per acre
- Diversity: Normalized ratio of population to jobs
- Destination Accessibility: Proximity of neighborhoods to regional destinations
- Distance to Transit: Number of people served by traditional transit service areas

Specific formulas used to calculate each variable are available on page 9 of the ***Technical Scenario Report***.

To determine changes in VMT, the consultant team calculated the percent change between these variables in the Trend scenario and the alternative scenarios and then applied elasticity values to weight the impact of changes in each variable on changes in VMT. The consultant team used the following elasticity values developed by Ewing and Cervero:

- Design: -0.12

[2] Ewing, Reid, and Robert Cervero. 2010. Travel and the Built Environment. *Journal of the American Planning Association* 76(3): 265-294.

- Density: -0.04
- Diversity: -0.02
- Destination Accessibility: -0.20
- Distance to Transit: -0.05

With trend and alternative scenario VMT derived from the Cape Cod Commission transportation model and 5D analysis, the consultant team allocated the resulting change in VMT among the four vehicle types based on the Cape Cod Commission transportation model: (1) passenger vehicles, (2), light duty vehicles, (3), medium trucks, and (4) heavy trucks. The consultant team then calculated the total change in consumption of each fuel type (gasoline and diesel) based on the fuel split and average fuel efficiency. Finally, the consultant team multiplied the carbon equivalent content per gallon for each fuel by the change in consumption to arrive at the change in GHG emissions. Because assumptions for mode mix and technology adoption were kept constant across all scenarios, relative GHG reductions were not different from relative VMT reductions. Scenario analysis used the following baseline assumptions for vehicles and fuels:

- Fuel Consumption:
  - Car: 35 miles per gallon
  - Light, Medium, and Heavy Trucks: 20 miles per gallon
- Mode Split:
  - Heavy Trucks: 0.3%
  - Medium Trucks: 2.1%
  - Light Trucks: 8.7%
  - Cars: 88.8%
- Carbon Content

## Opportunities to Enhance Baseline Data

Throughout the scenario development and evaluation processes, the Volpe Center and the consultant team have documented opportunities to enhance the baseline data and analysis used in the Pilot Project. These opportunities are presented below:

- Baseline data and projections
  - Both the MassDOT and Cape Cod Commission TransCAD models exhibited inconsistencies compared to other land use and population data. Employment quantities did not correspond well to mapped employment areas in both models and the MassDOT model's population change projections were low compared to other estimates. To address the former issue, the consultant team suggests applying a single trend growth pattern to both the transportation model and the scenarios.
  - U.S. Census 2010 projections were not available at the time of preliminary scenario development and, therefore, could not be incorporated into the Pilot Project. As these newer estimates might suggest flat or even declining growth for the 2030 horizon year, the consultant team suggests that the Cape Cod Commission may want to consider them in any future scenario development.
  - The consultant team assigned bounds to the changes in VMT that could result from its 5D analysis to avoid overestimation. These bounds are documented on page 10 of their *Technical Scenario Report* but may need to be adjusted based on an updated regional transportation model.

- Region-specific analysis
    - The scenario development and analysis were not able to capture the intricacies of Cape Cod's seasonal population variations. PlaceMatters was able to develop general summer population multipliers for each town based on existing summer population figures and vacant housing unit data from the U.S. Census 2000, but these multipliers were not incorporated into their analysis. In its ***Technical Scenario Report***, the consultant team proposes a methodology to further explore the winter/summer population dynamics for the 2030 horizon year.
    - The consultant team did not apply region-specific elasticity values to its 5D analysis. Therefore, the Cape Cod Commission can adjust the elasticity values applied to the 5D variables in order to account for regional factors that may influence their impact on changes in VMT.
    - Reliable region-specific estimates in mode and fuel type split were not available for the consultant team's analysis. If these were developed for the Baseline and Trend scenarios, the mode and fuel split could be manipulated as a variable in developing alternative scenarios. That is, stakeholders could establish a desired split between gasoline, diesel, and alternative fuels and between passenger car and type of truck in the Refined scenario. The Cape Cod Commission could also add specific transit and non-motorized mode assumptions.
- Transit:
    - Access to transit, used as a 5D variable and performance indicator in developing the Refined scenario, was calculated using a simple circular buffer for each transit stop that did not consider the street network. Introducing the street network into the calculation of transit accessibility would have more accurately captured how riders can walk, bicycle, or drive to the station but would have significantly increased the time needed to calculate scenario performance in a workshop setting. However, the consultant team suggests that future development of the Refined scenario could balance accuracy and efficiency by using the circular buffer approach during workshops and meetings and then supplementing it with a post analysis using the street network.
    - The access to transit stop buffer did not consider the Cape Cod Regional Transit Authority flag zone, in which riders can flag the bus to stop along the corridor, thus increasing the effective service area. This could be addressed by creating a linear corridor buffer for the flag zone area.
    - The current CommunityViz model cannot account for the impact of service frequency, fare levels, or other amenities and marketing techniques on ridership, and therefore mode split, as transit was addressed in scenario development and evaluation through proxy measures of population and employees with access to transit. The model also does not capture incoming potential ridership traffic from other modes – namely ferry and airplane. In its ***Technical Scenario Report***, the consultant team suggests several options for introducing ridership changes into scenario analysis, including developing ridership estimates from other measures, including ferry and plane ridership, and conducting a transit stop suitability analysis based on the allocation of new population and employment in the Refined scenario. Alternatively, a ratio of the existing "access to transit" measure to existing total system ridership could be extrapolated to develop an estimated ridership figure for the 2030 horizon year.

- Some existing and proposed transit services – such as the B-bus service and potential Cape Cod National Seashore beach parking shuttles[3] – were not included in the model but could be added.

[3] See *Cape Cod National Seashore: Integrated Parking and Transit Plan* (**http://www.volpe.dot.gov/interagencypilotproject.html**).

# Appendix A: Full List of Performance Indicators, Data Dependencies, and Importance Ratings

| Indicator | Importance Rating (1-5) | | Notes |
|---|---|---|---|
| | Planning Group/Technical Committee Average | PlaceMatters | |
| **Vehicle Miles Traveled** | | | |
| VMT for total study area | 5.0 | 5 | |
| VMT by town | 4.9 | 5 | |
| VMT per capita | 4.0 | 5 | TransCAD dependent |
| Vehicle trips by mode | 5.0 | 5 | TransCAD dependent |
| **Implementation Costs of Mitigation Programs: Capital, Operational** | | | |
| Total study area | 4.1 | 4 | |
| Per program: | 3.7 | 3 | |
| alternative fuels | 3.8 | 3 | |
| alternative modes | 4.0 | 4 | |
| roadway hardware | 3.3 | 3 | |
| renewal generation in highway rights-of-way | 3.5 | 3 | |
| operational improvements | 3.6 | 3 | |
| pricing strategies | 3.4 | 3 | |
| Per capita | 2.8 | 3 | |
| New roadway centerline distance | 4.9 | 5 | TransCAD dependent |
| New bike lane centerline distance | 4.9 | 5 | |
| **Preservation of Natural/Existing Ecosystems: Total Study Area Indicators** | | | |
| Area consumed by sea-level rise | 4.5 | 4 | |
| Open space consumed by development | 3.8 | 3 | |
| High-value conservation lands/wetlands consumed by development | 4.1 | 3 | |
| New development on or near critical or endangered habitat: dwelling units, roadways, rail | 3.9 | 3 | |
| New dwelling units within 1/2 mile of the projected 20-year shoreline | 4.1 | 4 | |
| New impervious surfaces | 3.6 | 3 | |
| **Land Use, Social, and Economic Indicators for New Dwelling Units** | | | |
| Population: full-time and part-time | 4.8 | 5 | |
| Dwelling units: by study area, by town, and by density | 4.0 | 4 | |
| Employment: in season and off-season | 3.8 | 4 | |
| Population density outside of open space | 3.0 | 3 | |

| Indicator | Importance Rating (1-5) | | Notes |
|---|---|---|---|
| | Planning Group/Technical Committee Average | PlaceMatters | |
| Land use mix | 3.8 | 4 | |
| Building energy consumption | 2.9 | 2 | Use current averages w slider bar for level of improvement |
| **Accessibility Indicators for New Dwelling Units** | | | |
| Average distance to centers | 3.9 | 4 | |
| Average distance to shoreline | 3.5 | 3 | |
| Average distance to gateways | 2.8 | 3 | |
| Population in transit service areas | 4.1 | 4 | |
| Medium and high density dwelling units near centers | 3.5 | 4 | |
| Medium and high density dwelling units near transit | 4.3 | 4 | |
| Transit service area coverage | 4.3 | 4 | |
| Bicycle network coverage | 3.6 | 3 | |
| **Transportation Energy Use** | | | |
| Total study area | 4.8 | 5 | TransCAD dependent |
| By town | 4.7 | 5 | TransCAD dependent |
| Per capita | 4.1 | 5 | TransCAD dependent |
| On-road fuel consumption per capita | 3.9 | 5 | TransCAD dependent |
| By transportation source or program: | 4.0 | 4 | TransCAD dependent |
| conventional internal combustion passenger vehicles | 4.0 | 4 | |
| gas-electric hybrids | 4.0 | 4 | |
| flexible fuel vehicles | 4.0 | 4 | |
| passenger rail | 3.9 | 4 | |
| bus or BRT fleet | 3.9 | 4 | |
| alternative fuel mix | 3.0 | 4 | |
| electric utility energy used for plug-in hybrids or all-electric vehicles | 3.4 | 3 | |
| **Greenhouse Gas, Ozone and Particulate Matter Indicators: CO2, CO, CH4, SF6, HFC, NOx, ROG, PM10, PM2.5** | | | |
| Total study area | 4.4 | 4 | TransCAD dependent |
| By town | 4.4 | 4 | TransCAD dependent |
| Per capita | 3.6 | 4 | TransCAD dependent |
| By transportation source or program: | | | TransCAD dependent |
| conventional internal combustion passenger vehicles | 3.9 | 3 | |
| gas-electric hybrids | 3.9 | 3 | |
| flexible fuel vehicles | 3.9 | 3 | |
| passenger rail | 3.8 | 3 | |
| bus or BRT fleet | 3.8 | 3 | |
| alternative fuel mix | 3.6 | 3 | |

| Indicator | Importance Rating (1-5) | | Notes |
|---|---|---|---|
| | Planning Group/Technical Committee Average | PlaceMatters | |
| electric utility energy used for plug-in hybrids or all-electric vehicles | 4.1 | 4 | |