A Systematic Approach to Estimate GWP from Pavement Vehicle Interaction Using Canadian LTPP Data

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Introduction

Research Problem

- Pavement vehicle interaction (PVI) is one of the significant components in the use phase of pavement life cycle assessment.
- This component has attribution with excess fuel consumption, resulting in an increase in the global warming potential (GWP).
- 'A big question: how do various climatic parameters including precipitation, temperature, and freezing index influence the PVI and subsequent GWP?' is answered.
- Canada is the second largest country in the world and different climatic regions can be found in each of its ten provinces and three territories.
- A new, climate-based clustering approach—rather than geometric boundaries is introduced for climate impact analysis.

Objectives

To better understand the PVI effect in asphalt pavement in the Canadian climate conditions.

Test Sites: LTPP Test Sections of Canada

Asphalt Concrete Layer- 1.4inch
Asphalt Concrete Layer- 1.8inch
Granular Base Layer-9.9inch
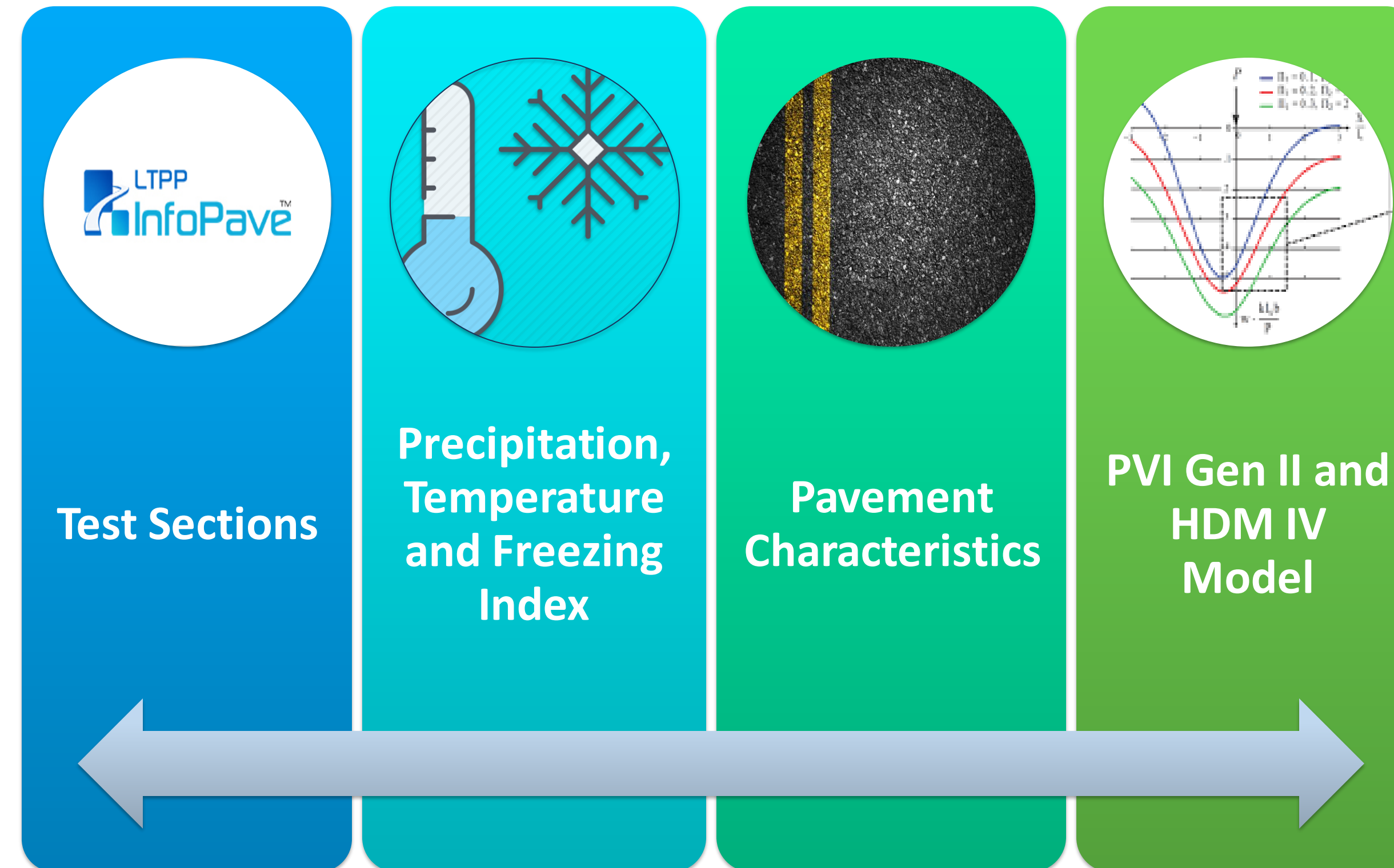Granular Subbase Layer-11.2inch
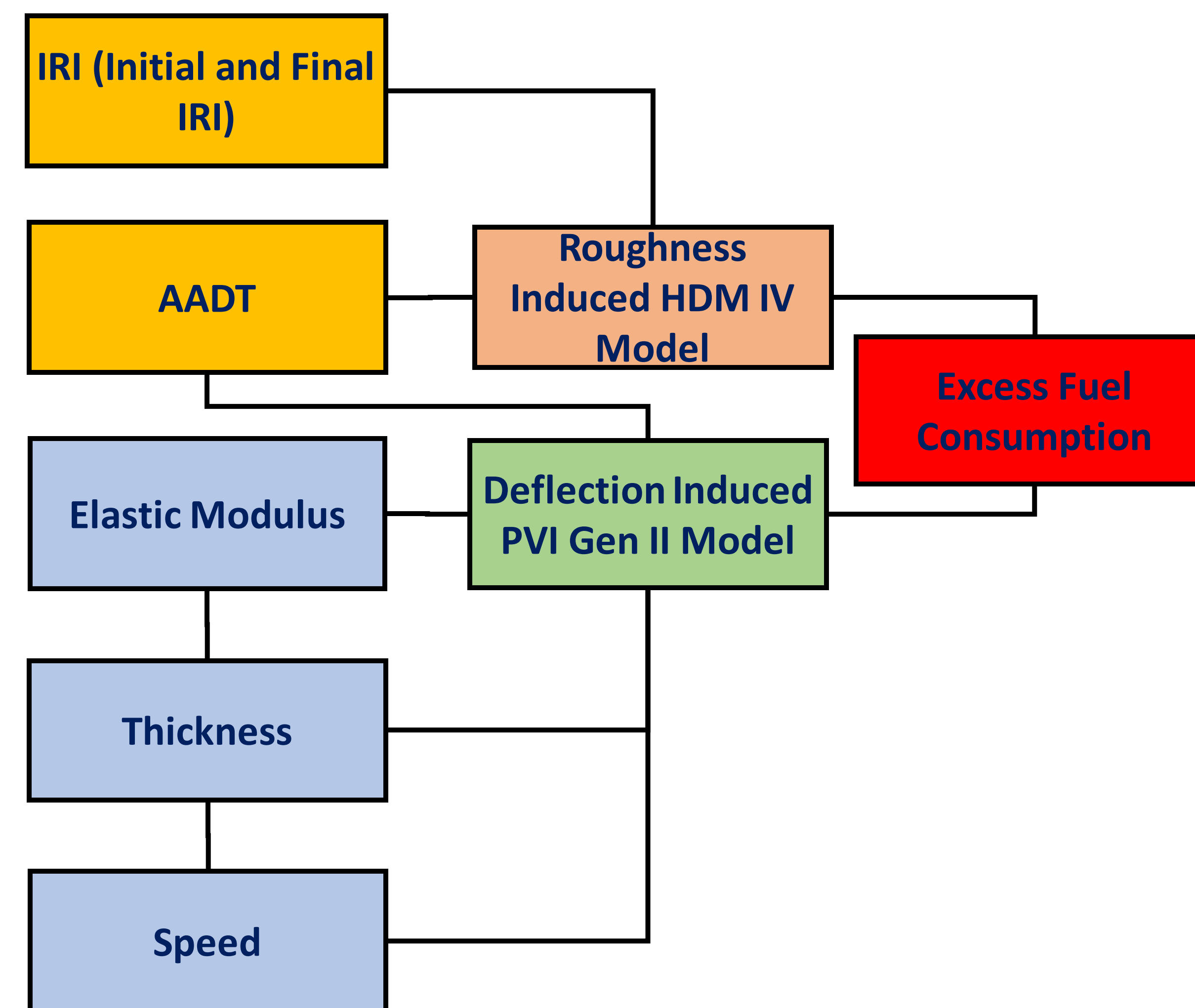Subgrade-54inch

Figure 1: Cross Section of TS 09

- 22 test sections (TS) (Out of 141 test sections)
- Alberta(3), British Columbia (3), Manitoba(2), Newfoundland(2), New Brunswick(3), Ontario(3), Quebec(3), Saskatchewan(3)

Figure 2: Field Survey of TS 09

Methodology

Data and Data Collection

Test Sections | Precipitation, Temperature and Freezing Index | Pavement Characteristics | PVI Gen II and HDM IV Model

Pavement Characteristics

IRI (Initial and Final IRI)
AADT
Roughness Induced HDM IV Model
Elastic Modulus
Deflection Induced PVI Gen II Model
Excess Fuel Consumption
Thickness
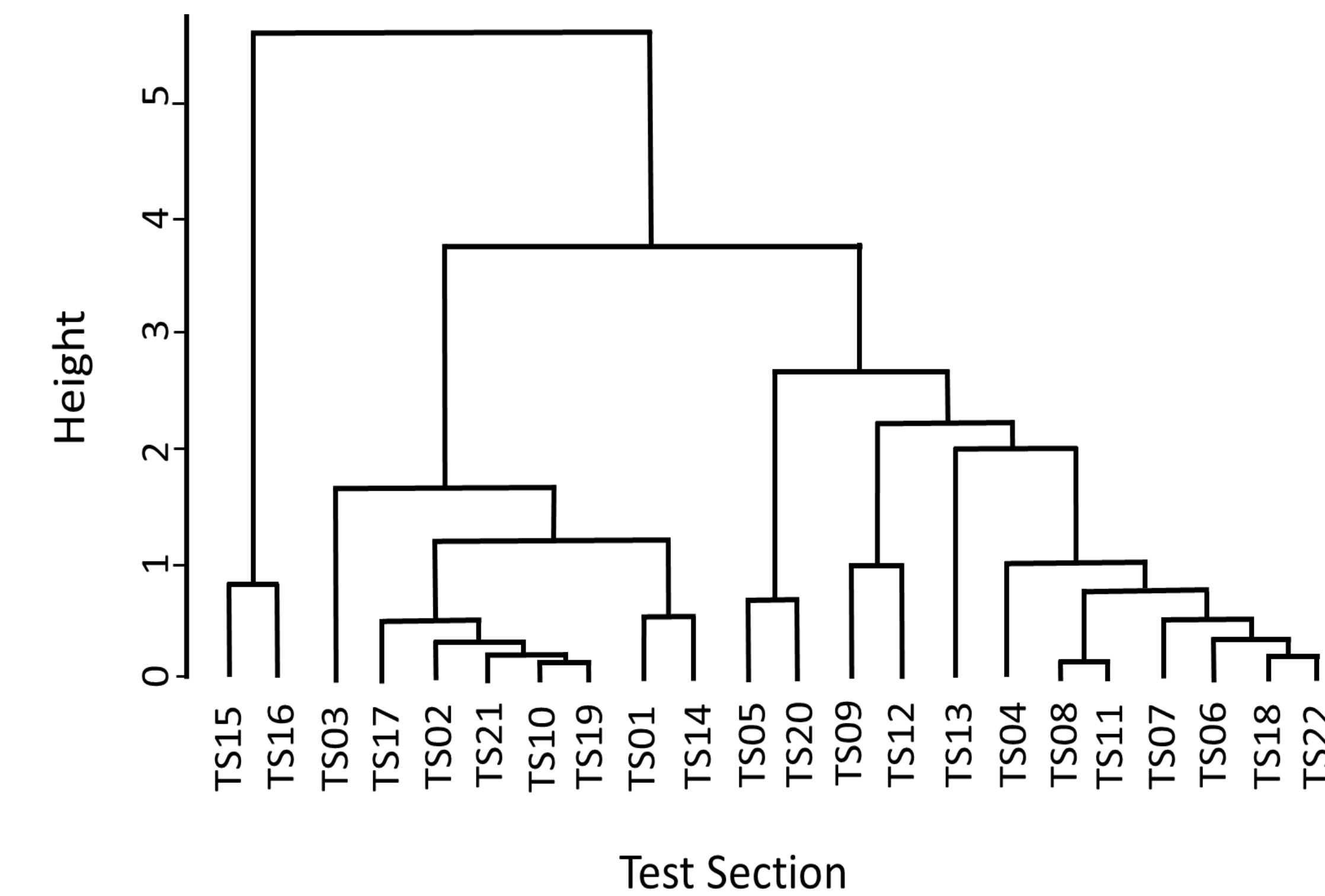Speed

HDM IV and PVI Gen II Model

$$\delta E = E_c \left(IRI_{FInal} - IRI_{Initial} \right)$$

$$Total\ excess\ fuel\ consumption = \int_{t=initial\ time}^{t=final\ time} \delta E * L(t)\ dt$$
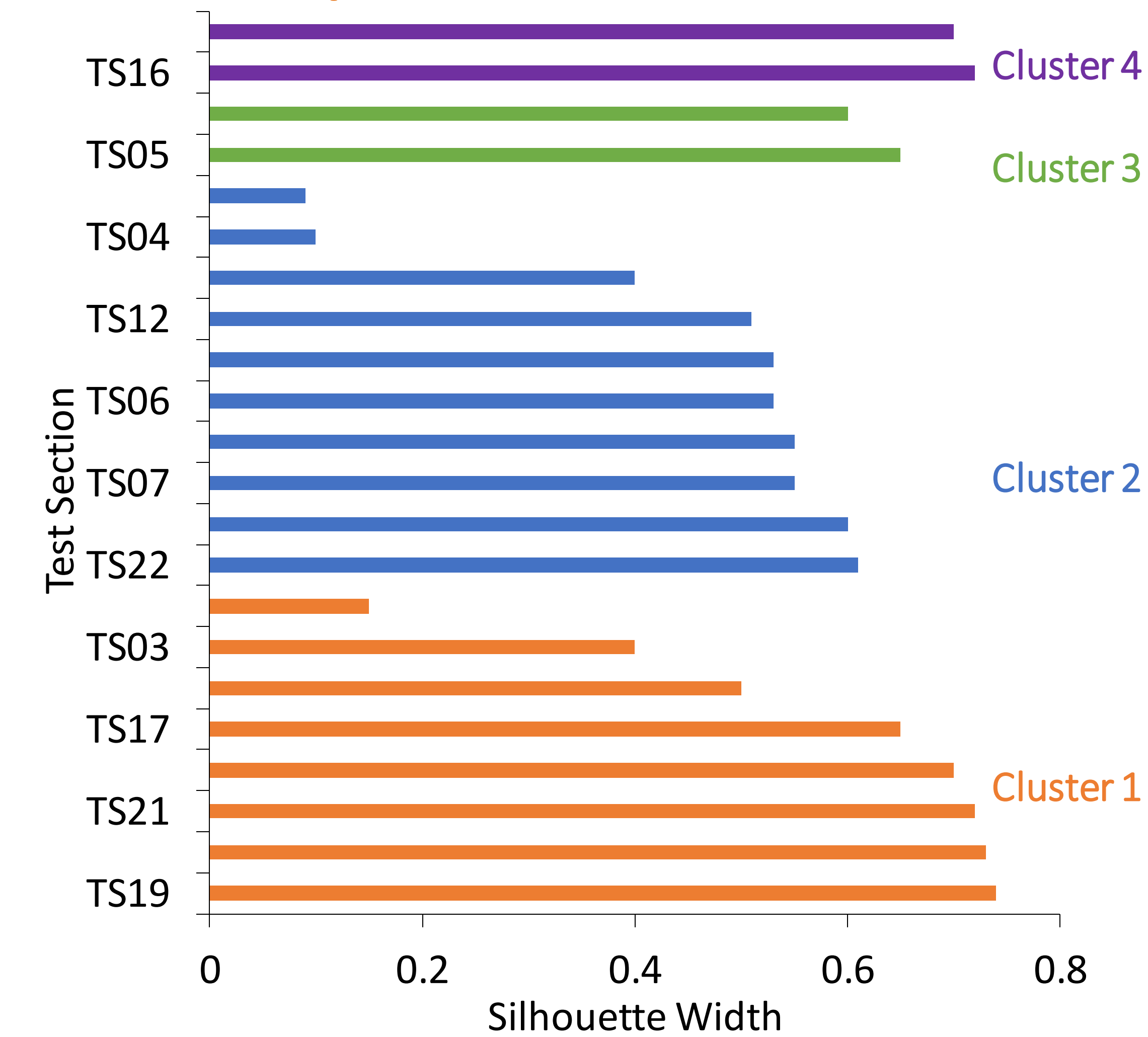
$$\delta E = \frac{c_{cr}}{c} * \frac{P^2}{bkl_s^2} * F\left(\frac{c}{c_{cr}} ; \frac{\tau(T)c_{cr}}{l_s} \right)$$

Data Analysis

Cluster of Test Sections Using a Dendrogram

Test Section

### Refinement of Clusters Using Silhouette Plot Technique

Silhouette Width

Overall Climate Conditions for Each Cluster

	Average Annual Precipitation	Average Annual Temperature	Average Annual Freezing Index
Cluster 1	Medium	Low	High
Cluster 2	High	Medium	High
Cluster 3	Medium	Medium	Medium
Cluster 4	High	High	Low

Results

GWP Emission due to Roughness Based PVI
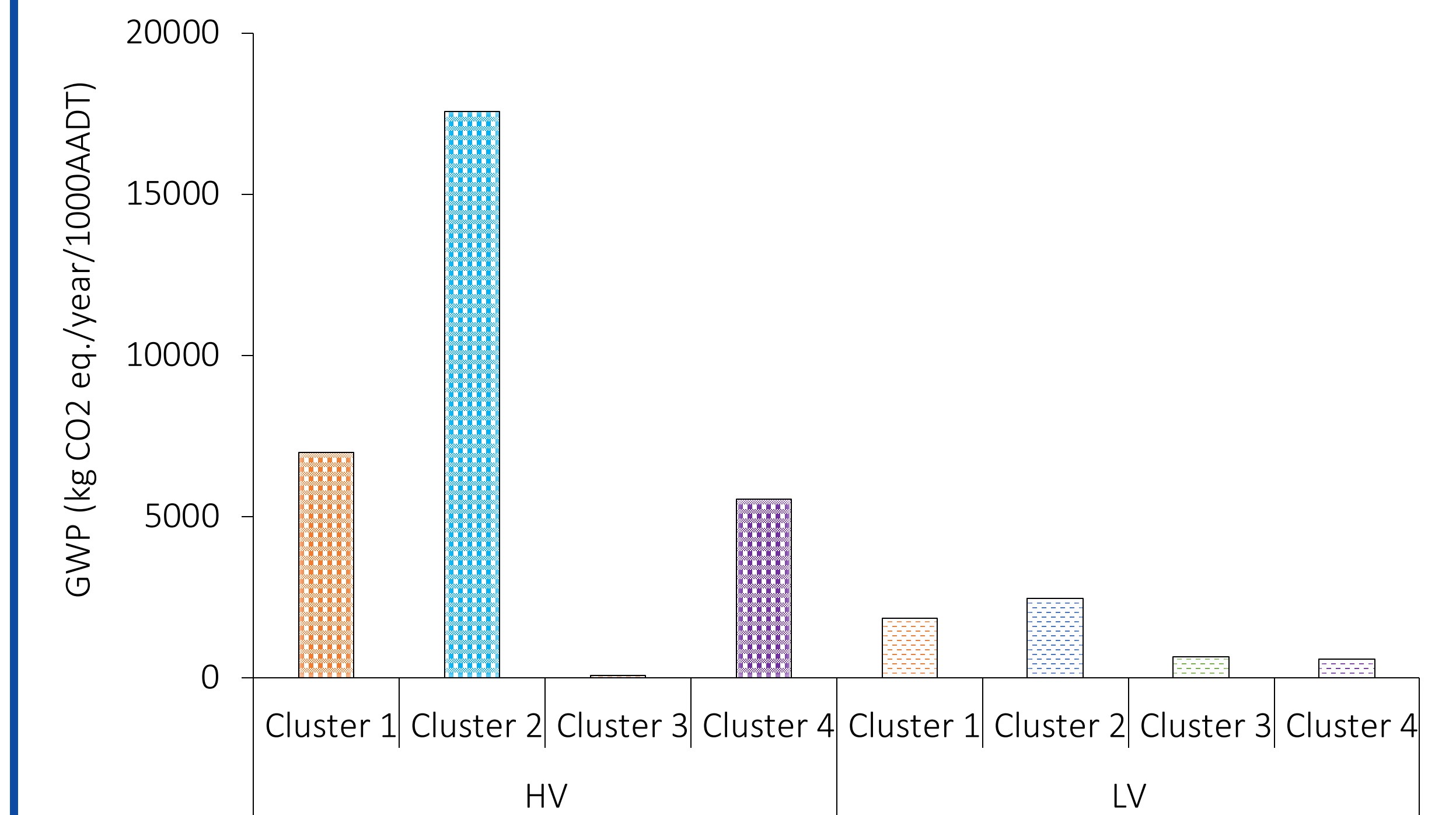
GWP Emission due to Deflection Based PVI
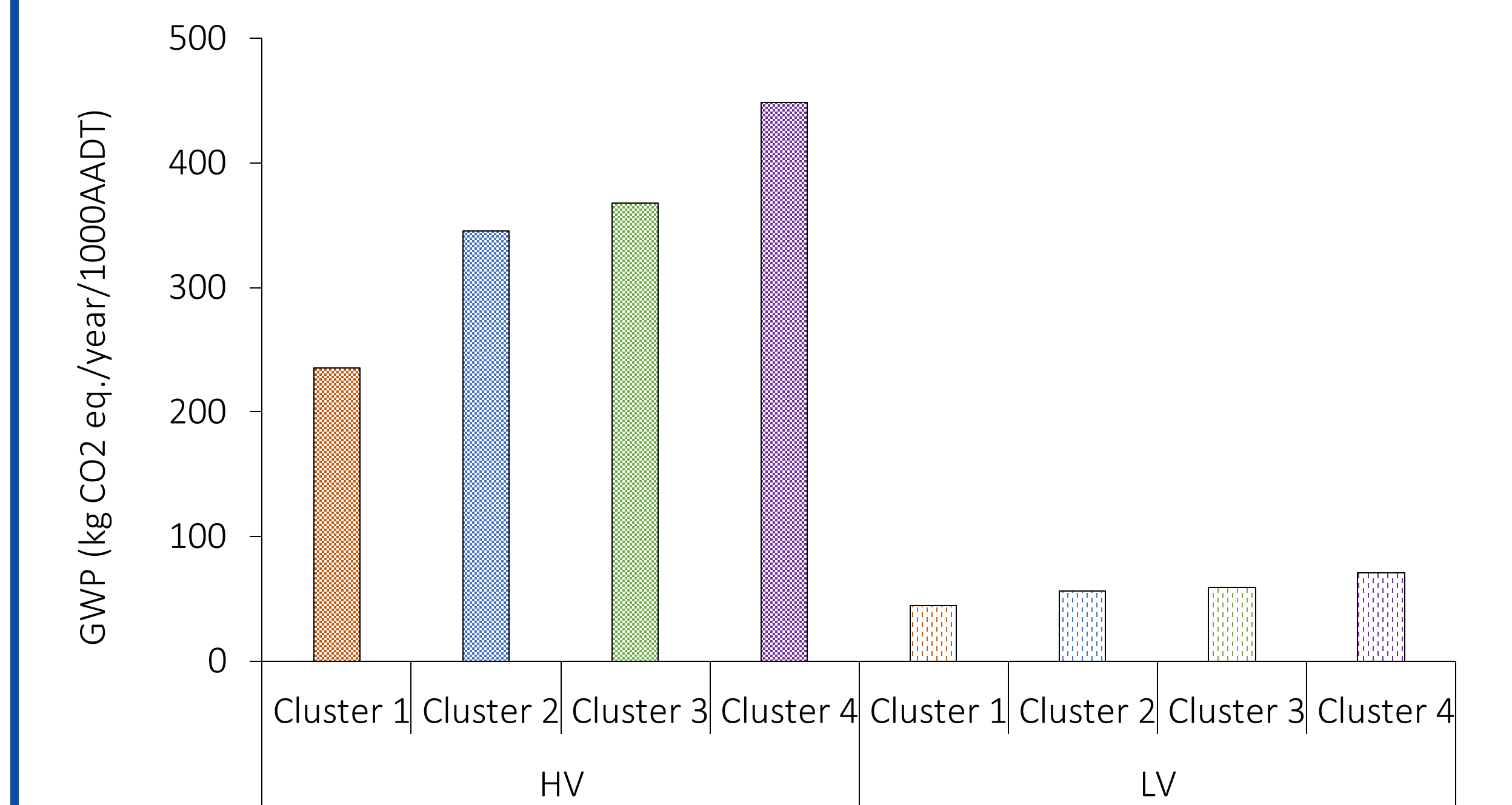
Conclusions

- A new systematic "climate based clustering" approach is introduced rather than considering geometric boundaries for environmental impact analysis from the road system.
- From IRI perspective, the clusters can be ranked as follows Cluster 2 > Cluster 1 > Cluster 3 > Cluster 4. In Cluster 2, the climate parameters included a high annual precipitation, high annual freezing index, and medium annual temperature.
- For deflection based PVI effects, Cluster 4 had the maximum vehicle load both for HV and LV, and the minimum subgrade stiffness. These factors combined emitted the highest GWP in Cluster 4 among all the clusters
- For the same number of vehicles (1000 AADT), heavy vehicles are dominant rather than LV for GWP emission, considering both cases, roughness and deflection based PVI.