TRIP GENERATION MODELLING USING LINEAR REGRESSION AND NEURAL NETWORKS (MLP)

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OBJECTIVES

- Develop trip generation models using Linear Regression & MLP.
- Compare model performance.
- Identify key variables affecting daily trip generation.

Literature Review

PAPER-Analysis of Freight Trip Generation Model for Food and Beverage in Belo Horizonte (Brazil)

OBJECTIVE:

To create a statistical model to predict the number of daily freight trips attracted by pubs and restaurants in Belo Horizonte.

Variables Used

- (NT): Number of daily freight trips attracted by an establishment.
- A: The Area of the establishment, measured in square meters (m^2).
- E: The Number of employees at the establishment.

Regression Model Equations

1. **Model 1 (Area):**
   - NT = 0.98 + 0.0016A
   - R^2 = 0.48
2. **Model 2 (Employee):**
   - NT = 1.04 + 0.019E
   - R^2 = 0.55
3. **Model 3 (Multiple Regression):**
   - NT = 1.01 + 0.014E + 0.00049A
   - R^2 = 0.55

Methodology

MODELING STRATEGY

PHASE 1: BASELINE MODEL LINEAR REGRESSION

- Applied Linear Regression to establish an initial benchmark.

PHASE 2: ADVANCEMENT TO MLP NEURAL NETWORK

- Introduced MLP to learn deeper, non-linear patterns.

DATASET

DATA SOURCE: Household travel characteristics survey.

OBSERVATIONS: 1,813 rows of data.

Dependent Variable: Number of Trips

Independent Variables: A mix of 15+ variables, including:

- Ward, HT, Commercial, Residential, Income, EarnMem, Hsize, Area_sqm, Vehicles, etc.

DATA PRE-PROCESSING

Step 1: Label Encoding

- **Input:** Text categories (e.g., Own House, Rented)
- **Action:** Converted to numerical labels
  - Own House → 1
  - Rented → 2
- **Purpose:** Makes categorical attributes usable for ML models.

Step 2: Unit Normalization

- **Input:** Mixed area units (GAJ, Sq. Ft, etc.)
- **Action:** Standardized all units to **Square Meters**
  - GAJ → sqm using: **Area (sqm) = Area × 0.828**
  - Sq. Ft → sqm using: **Area (sqm) = Area × 0.0929**
- **Purpose:** Ensures consistent scale for accurate model training.

Step 3: Feature Engineering

- **Action:** Created derived ratio variables to capture density and socio-economic structure.
- Examples:
  - **EarnRatio = Earning Members / Household Size**
  - **IncomeR = Income / Household Size**
  - **VehiclesR = Vehicles / Household Size**

Purpose: Helps ML models learn deeper patterns beyond raw variables.

Linear Regression 1

Correlation Coefficient: 0.442

R Square (R^2): 0.196

Sample Size (N): 1813

Adjusted R^2: 0.189

Std. Error of Estimate: 1.879

Linear Regression 2

Correlation Coefficient	0.433
R Square (R^2)	0.187
Sample Size (N)	1813
Adjusted R^2	0.184
Std. Error of Estimate	1.885

Linear Regression 2 was developed after removing statistically insignificant variables from MLR Model 1.

Linear Regression: Performance Analysis

The Linear Regression model explained less than 20% of the variation ($R^2 = 0.196$), indicating a very weak predictive ability.

Low R^2 and high error values show that the relationships between variables are non-linear and cannot be captured by a straight-line model.

Because Linear Regression fails to model these complex patterns, an advanced model like MLP/ANN is required to achieve higher accuracy.

Advanced Model

1. **Neural Network Multilayer Perceptron (MLP) Model**

Methodology

- **Dataset:** 1,813 rows of observations.
- **Target Variable:** Trips (Number of daily trips)
- **Independent Variables:** A mix of 15+ variables, including:
    - Ward, HT, Commercial, Residential, Income, EarnMem, Hsize, Area_sqm, Vehicles, etc.
- **Validation:** To prevent overfitting, all models were validated using either a **70/30 Train/Test split.**

Neural Network Multilayer Perceptron (MLP) Model

- An MLP is a powerful machine learning model, inspired by the human brain, that is excellent at finding the **complex, non-linear patterns**.

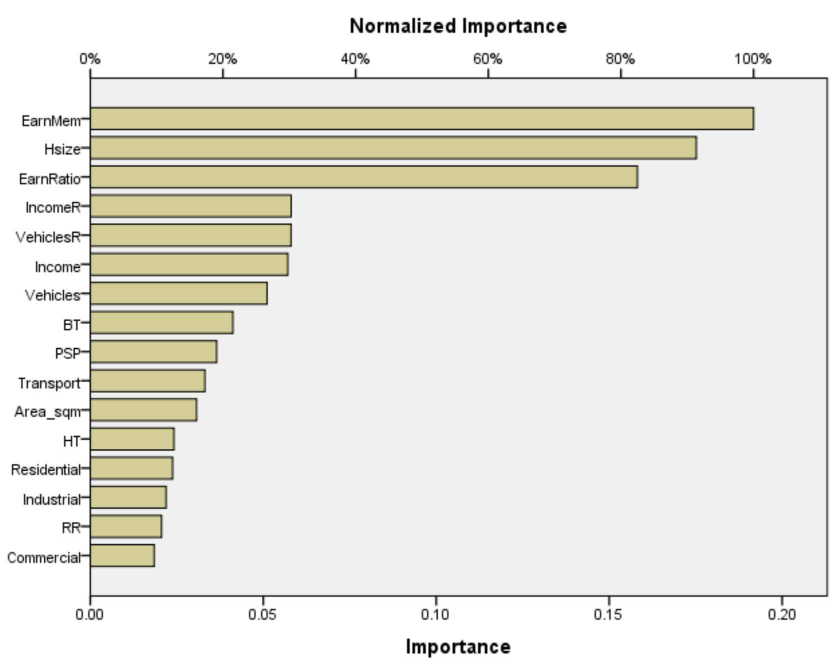
R2=1−(SSE/SST)
SST = Total sum of squares
SST=(N−1)×Variance
Variance of trip= 4.375

Metric	R^2
Training R^2	0.942
Testing R^2	0.973

Model Summary		
Training	Sum of Squares Error	456.541
	Relative Error	.733
	Stopping Rule Used	1 consecutive step(s) with no decrease in error[a]
	Training Time	0:00:00.33
Testing	Sum of Squares Error	213.216
	Relative Error	.781

Dependent Variable: Trips
a. Error computations are based on the testing sample.

Independent Variable Importance



Independent Variable Importance		
	Importance	Normalized Importance
BT	.041	21.5%
HT	.024	12.6%
Hsize	.175	91.4%
EarnMem	.192	100.0%
Vehicles	.051	26.6%
Income	.057	29.8%
Area_sqm	.031	16.0%
EarnRatio	.158	82.5%
VehiclesR	.058	30.3%
IncomeR	.058	30.3%
Commercial	.018	9.6%
Industrial	.022	11.4%
PSP	.037	19.1%
RR	.021	10.7%
Residential	.024	12.4%
Transport	.033	17.3%

COMPARISON

R Square (R^2)

19.6%

Linear Regression

Poor Fit (Data is not linear)

R Square (R^2)

94.2%

Neural Network (MLP)

Improvement over linear model

CONCLUSIONS

Performance of Linear Regression vs. MLP Neural Network

- **Linear Models are Insufficient:** The standard Linear Regression model was a very poor fit **($R^2 < 20\%$)** for this dataset, proving that the relationships between household/land-use data and trip generation are not linear.
- **MLP Models are Superior:** The Neural Network (MLP) model was extremely successful **($R^2 > 94\%$)**, demonstrating its ability to capture the complex, non-linear patterns that the linear model missed.
- **Household Factors are Key Drivers:** The MLP model identified that household characteristics, specifically 'Earning Members' and 'Household Size', are the most important factors in predicting trips.

REFERENCE

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2. Oludolapo, O. A., Jimoh, A. A., & Kholopane, P. A. (2012). Comparing performance of MLP and RBF neural network models for predicting South Africa's energy consumption. *Journal of Energy in Southern Africa*, *23*(3), 40-46

THANK YOU