Appraisal of Different Artificial Intelligence Techniques for Travel Demand Analysis

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Structure of the Presentation

- Introduction
- Evolution of travel demand modeling approach
- Appraisals of different AI techniques applied in travel demand analysis
- Comparative performance measures between AI techniques and traditional statistical methods
Introduction

Increase in urban population

Increase in urban travel demand

• Smart city
• National Electric Mobility Mission Plan 2020
• Automotive Mission Plan 2026

• Change in lifestyle
• Improvement in technology
• New emerging modes

• Traffic congestion
• Pollution
• Road accidents

Need – creation of sustainable travel environment

Required: accurate impact assessment of the policy

policy-sensitive, efficient, **disaggregate** travel demand model
Need of the Research

Travel behaviour modelling for heterogeneous Indian population: complex and challenging

Performance of traditional methods with data associated with uncertainties and complex system: Poor

ICTs and Govt. initiatives
- ITS
- mobile app-based transportation services
- open-source databases
- web services

Increasing application of AI in travel demand assessment

AI techniques:
- Cost-effective
- Reliable: quantitative and qualitative data
- Good: data with uncertainties and probabilities

Access to Big-data sets
Research Framework

**Research Question**
1. What is the progress in travel demand analysis in India with respect to global scenario?
2. What are the contributions of AI techniques in travel demand analysis?
3. Which model has a better prediction accuracy? - econometric based model or AI based model?

**Aim:** To identify potentials, challenges, and future prospectus in application of AI techniques in travel demand analysis in India

**Objectives:**
1. Analysis of the evolution of travel demand modelling approach across the globe and in India
2. Appraisals of different AI techniques applied in travel demand analysis
3. Comparative performance measures between AI techniques and traditional statistical methods
Searching Criteria:
- Key words: Travel demand + AI/ Data mining
- Only peer reviewed articles
- Review articles excluded
- Since 2010

SCOPE OF THE RESEARCH:
- Review based approach
- Limitation - Arguments regarding data-intensive nature of AI technique
EVOLUTION OF TRAVEL DEMAND MODELLING APPROACH
### Paradigm Shift from ‘Statistical-based’ to ‘Simulation-based’ Approach

<table>
<thead>
<tr>
<th>Year</th>
<th>Model Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1950s</td>
<td>Aggregate Spatial Interaction Model</td>
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<tr>
<td>1970s</td>
<td>Advancement in behavioral research- Activity Based Models</td>
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<tr>
<td>1978</td>
<td>Econometric based Models</td>
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<tr>
<td>1977</td>
<td>Constraints based Activity based Models</td>
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<tr>
<td>2000</td>
<td>Computational Process Models</td>
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<tr>
<td>2007</td>
<td>Agent-based Modeling</td>
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</tbody>
</table>

Advancement in behavioral research and activity-based models marked in red.
APPRAISALS OF DIFFERENT AI TECHNIQUES APPLIED IN TRAVEL DEMAND ANALYSIS
Application of various AI techniques in Travel Demand Analysis

• Formulation of empirical dynamic models
• Part of travel demand prediction model
• Prediction model to estimate deterioration of transportation infrastructure as a function of traffic, construction, and environmental factors - non-linear input - output relationship
• Provision of smart transportation facilities - ITS – amalgamation of multiple AI algorithms - deep reinforcement learning techniques
  o Automatic signal control of traffic at road intersections
  o Ramp metering on freeways
  o Dynamic route guidance
  o Positive train control on railroads
Application of various AI techniques in Travel Demand Analysis

- Behavioral Choice Analysis: Swarm Intelligence, Fuzzy, ABM, RFDT, NF, Bayesian, ANN
- Vehicle Routing: GA, ACO, BCO
- Optimization: GA, Swarm Intelligence, Fuzzy
- Travelling Salesman: BCO
- Integrated Landuse Transportation Planning: ANN
Application of various AI techniques in Travel Demand Analysis

Network Design Problem: GA, SA, ACO, AIS, ANN

Safety Management Plan: ANN

Traffic Conflict Resolution: GA, SA, ACO

Public Transport Regulation: AIS

Automated guided vehicle: GA
COMPARATIVE PERFORMANCE MEASURES BETWEEN AI TECHNIQUES AND TRADITIONAL STATISTICAL METHODS
Different Approaches of Travel Demand Models

- **Logit Models**
  - Multinomial Logit Model (MNL)
  - Nested Logit Model (NL)
  - Generalized Extreme Value Model (GEV)

- **Data Mining Techniques**
  - Artificial Neural Network (ANN)
  - Decision Tree (DT)
  - Random Forest Decision Tree (RFDT)
  - Fuzzy Logic
  - Neuro-fuzzy model
Different Approaches of Travel Demand Models

- Inspired by Human neural System
- **No restriction** on input variables
- Good at **Non-linear complex** relations
- **Black-box**
- ANN > MNL – Delhi, Campania Region, South of Italy, San Francisco

- Supervised classification
- Easy to interpret
- ‘White Box’
- Less computational time
- Pre-classification
- Error due to bias and variance- over fitting – RFDT
- Chance of **persistence of error**
- Randomly chosen features
- RFDT (98.96%) > MNL (77.31%) - Delhi

- **capture vague/ linguistic expression**
- fuzzy Input Values
- No learning ability
- Fuzzy (70%) > MNL (40%) - Gujrat, PortBlair, Iran
- **NF: Complement drawbacks** of ANN and Fuzzy
- Pre-processing data
- Lack of **common framework**
- High Calibration (99.73%) and Validation (98.64%), Mumbai

Fuzzy & NF

(Cantarella & Luca, 2003), (Ravi Sekhar, 1999), (Xie, Lu, & Parkany, 2003)
Comparisons among ANN-MLP, ANN-RBF, SVM and MNL

• Mode choice model on work trip, Vadodara city, Gujarat, India
• Associated error: MNL: 0.34, SVM: 0.28, Boost tree models: 0.1598

• Mode choice model, Luxembourg
• Evaluating performance by Root Mean Square Error (RMSE) and Average Probability of Correct Assessment (APCA)

<table>
<thead>
<tr>
<th></th>
<th>APCA x100 (Overall)</th>
<th>APCA x100 (Car)</th>
<th>APCA x100 (PT)</th>
<th>APCA x100 (soft mode)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MNL</td>
<td>64.68 ± 1.16</td>
<td>78.48 ± 0.14</td>
<td>22.68 ± 0.95</td>
<td>7.29 ± 0.50</td>
</tr>
<tr>
<td>SVM</td>
<td>67.70 ± 3.81</td>
<td>7.96 ± 2.56</td>
<td>23.01 ± 0.83</td>
<td>26.49 ± 7.16</td>
</tr>
<tr>
<td>ANN-RBF</td>
<td>79.24 ± 4.54</td>
<td>80.96 ± 2.83</td>
<td>35.01 ± 6.71</td>
<td>31.27 ± 8.71</td>
</tr>
<tr>
<td>ANN-MLP</td>
<td>81.12 ± 1.12</td>
<td>85.10 ± 1.23</td>
<td>40.65 ± 2.27</td>
<td>25.63 ± 9.84</td>
</tr>
</tbody>
</table>

(Omrani, 2015)
Comparisons among ANN, SVM, NM, MNL and classification trees

• Mode choice model based on Dutch travel diary data
• Prediction performance of 6 machine learning classifiers
  ○ ANN with a single hidden layer of 48 neurons
  ○ SVM
  ○ Naive Bayes (NB)
  ○ MNL as baseline classifier
  ○ classification tree (Bagging, Boosting and RF)
• Sample Size: 69918
• Accuracy: overall proportion of correctly classified observations
• Sensitivity analysis proportion of correctly assigned observation for each class

(Julian & Marc, 2017)
Comparisons among ANN, SVM, NM, MNL and classification trees

- **Accuracy:**
  - RF - 0.91
  - Bagging - 0.91
  - MNL 0.561

- **Sensitivity analysis:**
  - PT more accurately followed by walking - all classifiers (except NB)
  - Car more accurately - NB
  - least accurately predicted - bike
  - Same pattern with respect to sensitivity analysis - all classifiers (except NB and MNL)

(Julian & Marc, 2017)
### Strength

- Efficient to deal with **big-datasets**
- Reliable: **quantitative and qualitative data**
- Good dealing with
  - data with **uncertainties and probabilities**
  - **Optimization problems**
- Gives **good fit** to observed data
- **Cost-effective**

### Challenges

- Selection of **appropriate method**
- Model interpretability (Black-box model)
- **Validation** for long-term prediction models
- Trade-off between computational **run-time and sample size**
Conclusion

- Prediction accuracy of any AI-based method (Fuzzy, ANN, Boost tree) is more efficient than the traditional statistical method in context of behavioral choice analysis in India.

- Future Research:
  - The content of narrow existing literature on travel demand analysis in India is limited to the comparisons between different econometric model and AI-based model - comparison efficiency among different AI techniques with an aim to find the most appropriate algorithm for behavioral analysis in India.
  - Integration of AI techniques with activity based travel demand modeling framework
  - Trade off between computational run time and sample size

- Demand for data-intensive and costly nature of AI technique - debatable topic - further research


References


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THANK YOU!