GOVERNMENT OF INDIA
MINISTRY OF HOUSING AND URBAN AFFAIRS

Appraisal of Different Artificial Intelligence Techniques for Travel Demand Analysis

Suchismita Nayak & Dr. Debapratim Pandit
Indian Institute of Science and Technology Kharagpur

UP METRO

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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

- Traffic congestion
- Pollution
- Road accidents

Need – creation of sustainable travel environment

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

Required: accurate impact assessment of the policy

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

policy-sensitive, efficient, **disaggregate** travel demand model

Need of the Research

Travel behaviour modelling for **heterogeneous** Indian population: **complex and challenging**

ICTs and Govt. initiatives

- ITS
- mobile app-based transportation services
- open-source databases
- web services

Access to Big-data sets

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

Increasing application of AI in travel demand assessment

AI techniques:

- **Cost-effective**
- Reliable: **quantitative and qualitative data**
- Good: data with **uncertainties and probabilities.**

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

Research Framework

Searching Criteria:

- Key words: Travel demand+ AI/ Data mining
- Only peer reviewed articles
- Review articles excluded
- Since 2010

Web of Science (96) | Scopus (140) | Science Direct (68)

↓

After Removing overlapped articles (225) + Articles on Travel demand models , ML

↓

India (37) | Outside India (234)

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

- **1950s** — Aggregate Spatial Interaction Model
- **1970s** — Advancement in behavioral research- Activity Based Models
- **1967** — Constraints based Activity based Models
- **1978** — Econometric based Models
- **2000** — Computational Process Models
- **2007** — Agent-based Modeling

APPRAISALS OF DIFFERENT AI TECHNIQUES APPLIED IN TRAVEL DEMAND ANALYSIS

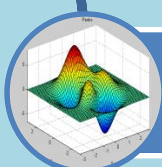
Application of various AI techniques in Travel Demand Analysis

- 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
    - Automatic signal control of traffic at road intersections
    - Ramp metering on freeways
    - Dynamic route guidance
    - Positive train control on railroads

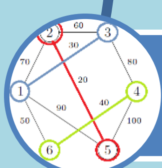
Application of various AI techniques in Travel Demand Analysis

- Behavioral Choice Analysis: Swarm Intelligence, Fuzzy, ABM, RFDT, NF, Bayesian, ANN

- Vehicle Routing: GA, ACO, BCO



- Optimization: GA, Swarm Intelligence, Fuzzy



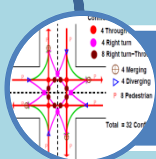
- Travelling Salesman: BCO

- 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

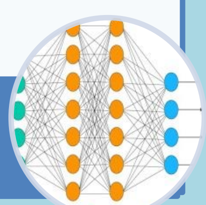
Different Approaches of Travel Demand Models

- **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

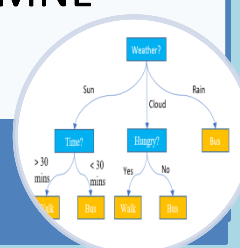
Different Approaches of Travel Demand Models

- 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



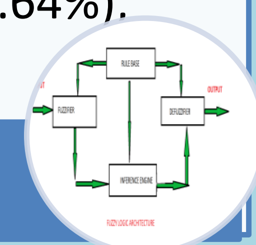
ANN

- 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



DT & RFDT

- **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

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(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)**

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

(Omrani, 2015)

Comparisons among ANN, SVM,NM, MNL and classification trees

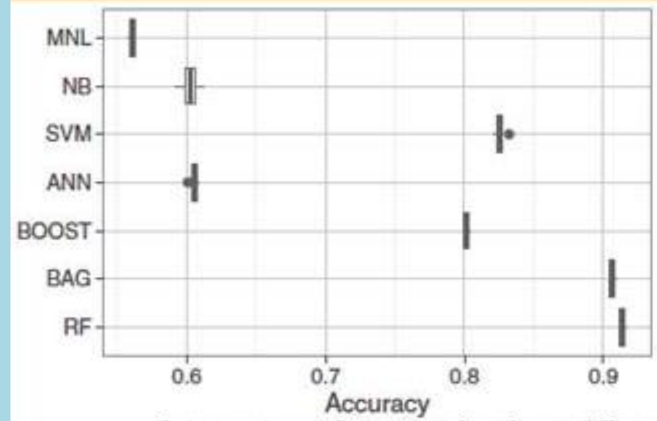
- **Mode choice model based on Dutch travel diary data**
- Prediction performance of **6 machine learning classifiers**
  - ANN with a single hidden layer of 48nuerons
  - SVM
  - Naive Bayes (NB)
  - MNL as baseline classifier
  - classification tree (Bagging, Boosting and RF)
- Sample Size: 69918
-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

(Julian & Marc, 2017)

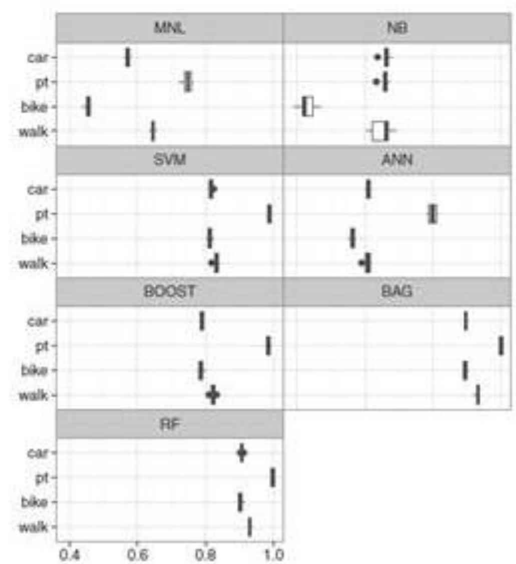
Comparisons among ANN, SVM,NM, MNL and classification trees

- **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)



Accuracy for each classifier



Sensitivity for each classifier

Strength and Weakness of Application of AI Techniques in Travel Demand Analysis

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

- Abduljabbar, R., Dia, H., Liyanage, S., & Bagloee, S. A. (2019). Applications of artificial intelligence in transport: An overview. Sustainability (Switzerland). https://doi.org/10.3390/su11010189
- ACTIVITY BASED TRAVEL BEHAVIOURAL STUDY AND MODE CHOICE MODELLING. (2015). International Journal of Innovative Research in Science, Engineering and Technology.
- Akğngör, A. P., & Doğan, E. (2009). An artificial intelligent approach to traffic accident estimation: Model development and application. Transport. https://doi.org/10.3846/1648-4142.2009.24.135-142
- Arentze, T. A., & Timmermans, H. J. P. (2004). A learning-based transportation oriented simulation system. Transportation Research Part B: Methodological. https://doi.org/10.1016/j.trb.2002.10.001
- Auld, J., & Mohammadian, A. (2009). Agent-Based Dynamic Activity Planning and Travel Scheduling Model: Model Framework. {TRB} 2009 Annual Meeting.
- Balmer, M., Axhausen, K., & Nagel, K. (2007). Agent-Based Demand-Modeling Framework for Large-Scale Microsimulations. Transportation Research Record: Journal of the Transportation Research Board. https://doi.org/10.3141/1985-14
- Bell, J. E., & McMullen, P. R. (2004). Ant colony optimization techniques for the vehicle routing problem. Advanced Engineering Informatics. https://doi.org/10.1016/j.aei.2004.07.001
- Bhat, C. R., & Koppelman, F. S. (2006). Activity-Based Modeling of Travel Demand. In Handbook of Transportation Science. https://doi.org/10.1007/0-306-48058-1_3
- Bowman, J. L., & Ben-Akiva, M. E. (2000). Activity-based disaggregate travel demand model system with activity schedules. Transportation Research Part A: Policy and Practice. https://doi.org/10.1016/S0965-8564(99)00043-9
- Bradley, M., & Vovsha, P. (2005). A model for joint choice of daily activity pattern types of household members. Transportation. https://doi.org/10.1007/s11116-005-5761-0
- Ceylan, H., & Bell, M. G. H. (2004). Traffic signal timing optimisation based on genetic algorithm approach, including drivers' routing. Transportation Research Part B: Methodological. https://doi.org/10.1016/S0191-2615(03)00015-8
- Cheng, L., Chen, X., De Vos, J., Lai, X., & Witlox, F. (2019). Applying a random forest method approach to model travel mode choice behavior. Travel Behaviour and Society. https://doi.org/10.1016/j.tbs.2018.09.002

References

- Dasgupta, D., Ji, Z., & Gonzalez, F. (2003). Artificial immune system (AIS) research in the last five years. 2003 Congress on Evolutionary Computation, CEC 2003 - Proceedings. https://doi.org/10.1109/CEC.2003.1299565
- Dia, H., & Rose, G. (1997). Development and evaluation of neural network freeway incident detection models using field data. Transportation Research Part C: Emerging Technologies. https://doi.org/10.1016/S0968-090X(97)00016-8
- Doğan, E., & Akgüngör, A. P. (2013). Forecasting highway casualties under the effect of railway development policy in Turkey using artificial neural networks. Neural Computing and Applications. https://doi.org/10.1007/s00521-011-0778-0
- Dorigo, M. (2006). Ant colony optimization and swarm intelligence : 5th international workshop, ANTS 2006, Brussels, Belgium, September 4-7, 2006 : proceedings. In Test. https://doi.org/10.1007/11839088_27
- Dorigo, M., & Gambardella, L. M. (1997). Ant colonies for the travelling salesman problem. BioSystems. https://doi.org/10.1016/S0303-2647(97)01708-5
- Dorigo, M., & Socha, K. (2007). Ant colony optimization. In Handbook of Approximation Algorithms and Metaheuristics. https://doi.org/10.1201/9781420010749
- Durand, N., & Alliot, J. M. (2009). Ant Colony Optimization for air traffic conflict resolution. Proceedings of the 8th USA/Europe Air Traffic Management Research and Development Seminar, ATM 2009.
- Ettema, D., Borgers, A., & Timmermans, H. (1993). Simulation model of activity scheduling behavior. Transportation Research Record. https://doi.org/10.3141/1551-12
- Fan, W., & Machemehl, R. B. (2006). Using a simulated annealing algorithm to solve the transit route network design problem. Journal of Transportation Engineering. https://doi.org/10.1061/(ASCE)0733-947X(2006)132:2(122)
- Ferdowsi, A., Challita, U., & Saad, W. (2019). Deep Learning for Reliable Mobile Edge Analytics in Intelligent Transportation Systems: An Overview. IEEE Vehicular Technology Magazine. https://doi.org/10.1109/MVT.2018.2883777
- Gärling, T., Kwan, M. P., & Golledge, R. G. (1994). Computational-process modelling of household activity scheduling. Transportation Research Part B. https://doi.org/10.1016/0191-2615(94)90034-5
- He, S. Y., Miller, E. J., & Scott, D. M. (2018). Big data and travel behaviour. Travel Behaviour and Society. https://doi.org/10.1016/j.tbs.2017.12.003

References

- Juremalani, J., & Chauhan, K. A. (2017). Comparison of Different Mode Choice Models for Work Trips using Data Mining Process. Indian Journal of Science and Technology. https://doi.org/10.17485/ijst/2017/v10i17/114376
- Kedia, A. S., Saw, K. B., & Katti, B. K. (2015). Fuzzy logic approach in mode choice modelling for education trips: A case study of Indian metropolitan city. Transport. https://doi.org/10.3846/16484142.2015.1081279
- Kirkpatrick, S., Gelatt, C. D., & Vecchi, M. P. (1983). Optimization by simulated annealing. Science. https://doi.org/10.1126/science.220.4598.671
- Kitamura, R., & Fujii, S. (2007). Two Computational Process Models of Activity-Travel Choice. In Theoretical Foundations of Travel Choice Modeling. https://doi.org/10.1016/b978-008043062-1/50012-9
- Kwan, M. (1997). GISICAS: AN ACTIVITY-BASED TRAVEL DECISION SUPPORT SYSTEM USING A GIS-INTERFACED COMPUTATIONAL-PROCESS MODEL.
- Langerudi, M. F., Javanmardi, M., Shabanpour, R., Rashidi, T. H., & Mohammadian, A. (2017). Incorporating in-home activities in ADAPTS activity-based framework: A sequential conditional probability approach. Journal of Transport Geography. https://doi.org/10.1016/j.jtrangeo.2017.04.010
- Lekshmi, G. R. A., Landge, V. S., & Kumar, V. S. S. (2016). Activity Based Travel Demand Modeling of Thiruvananthapuram Urban Area. Transportation Research Procedia. https://doi.org/10.1016/j.trpro.2016.11.100
- Li, J., Weng, J., Shao, C., & Guo, H. (2016). Cluster-Based Logistic Regression Model for Holiday Travel Mode Choice. Procedia Engineering. https://doi.org/10.1016/j.proeng.2016.01.310
- Li, X., Shi, X., He, J., & Liu, X. (2011). Coupling simulation and optimization to solve planning problems in a fast-developing area. Annals of the Association of American Geographers. https://doi.org/10.1080/00045608.2011.577366
- Lučić, P., & Teodorović, D. (2002). Transportation modeling: An artificial life approach. Proceedings of the International Conference on Tools with Artificial Intelligence. https://doi.org/10.1109/TAI.2002.1180807
- Lučić, P., & Teodorović, D. (2003a). Computing with Bees: Attacking Complex Transportation Engineering Problems. International Journal on Artificial Intelligence Tools. https://doi.org/10.1142/s0218213003001289

References

- Lučić, P., & Teodorović, D. (2003b). Vehicle Routing Problem With Uncertain Demand at Nodes: The Bee System and Fuzzy Logic Approach. https://doi.org/10.1007/978-3-540-36461-0_5
- Ma, T. Y. (2015). Bayesian networks for multimodal mode choice behavior modelling: A case study for the cross border workers of Luxembourg. Transportation Research Procedia. https://doi.org/10.1016/j.trpro.2015.09.040
- Malayath, M., & Verma, A. (2013). Activity based travel demand models as a tool for evaluating sustainable transportation policies. Research in Transportation Economics. https://doi.org/10.1016/j.retrec.2012.05.010
- Manoj, M., & Verma, A. (2015a). Activity-travel behaviour of non-workers belonging to different income group households in Bangalore, India. Journal of Transport Geography. https://doi.org/10.1016/j.jtrangeo.2015.10.017
- Manoj, M., & Verma, A. (2015b). Activity-travel behaviour of non-workers from Bangalore City in India. Transportation Research Part A: Policy and Practice. https://doi.org/10.1016/j.tra.2015.06.006
- Manoj, M., & Verma, A. (2017). A structural equation model based analysis of non-workers' activity-travel behaviour from a city of a developing country. Transportation. https://doi.org/10.1007/s11116-015-9636-8
- Masmoudi, A., Elkosantini, S., Darmoul, S., & Chabchoub, H. (2012). An Artificial Immune System for Public Transport Regulation. 9th International Conference of Modeling, Optimization and Simulation - MOSIM'12.
- Miller, E. J., & Roorda, M. J. (2003). Prototype Model of Household Activity-Travel Scheduling. Transportation Research Record: Journal of the Transportation Research Board. https://doi.org/10.3141/1831-13
- Pulugurta, S., Arun, A., & Errampalli, M. (2013). Use of Artificial Intelligence for Mode Choice Analysis and Comparison with Traditional Multinomial Logit Model. Procedia - Social and Behavioral Sciences. https://doi.org/10.1016/j.sbspro.2013.11.152
- Rao, S. P. V, & Sikdar, P. K. (1999). Calibration of fuzzy functions from revealed preference pattern in urban mode choice. International Conference in Computers in Urban Planning and Urban Management.
- Rasouli, S., & Timmermans, H. (2014). Activity-based models of travel demand: Promises, progress and prospects. International Journal of Urban Sciences. https://doi.org/10.1080/12265934.2013.835118
- Recker, W. W., McNally, M. G., & Root, G. S. (1986). A model of complex travel behavior: Part I-Theoretical development. Transportation Research Part A: General. https://doi.org/10.1016/0191-2607(86)90089-0

References

- Rodrigue, J.-P. (1997). Parallel modelling and neural networks: An overview for transportation/land use systems. Transportation Research Part C: Emerging Technologies, 5(5), 259–271. https://doi.org/https://doi.org/10.1016/S0968-090X(97)00014-4
- Sekhar, C. R. (2014). MODE CHOICE ANALYSIS: THE DATA, THE MODELS AND FUTURE AHEAD. INTERNATIONAL JOURNAL FOR TRAFFIC AND TRANSPORT ENGINEERING. https://doi.org/10.7708/ijtte.2014.4(3).03
- Sekhar, C. R., Minal, & Madhu, E. (2016). Mode Choice Analysis Using Random Forrest Decision Trees. Transportation Research Procedia. https://doi.org/10.1016/j.trpro.2016.11.119
- Seyedabrishami, S., & Shafahi, Y. (2013). A joint model of destination and mode choice for urban trips: A disaggregate approach. Transportation Planning and Technology. https://doi.org/10.1080/03081060.2013.851507
- Shabanpour, R., Javanmardi, M., Fasihozaman, M., Miralinaghi, M., & Mohammadian, A. (2018). Investigating the applicability of ADAPTS activity-based model in air quality analysis. Travel Behaviour and Society. https://doi.org/10.1016/j.tbs.2017.02.004
- Subba Rao, P. V., Sikdar, P. K., Krishna Rao, K. V., & Dhingra, S. L. (1998). Another insight into artificial neural networks through behavioural analysis of access mode choice. Computers, Environment and Urban Systems. https://doi.org/10.1016/S0198-9715(98)00036-2
- Subbarao, S. S. V., & Krishna Rao, K. V. (2013). Trip chaining behavior in developing countries: A study of Mumbai Metropolitan Region, India. European Transport - Trasporti Europei.
- Teklu, F., Sumalee, A., & Watling, D. (2007). A genetic algorithm approach for optimizing traffic control signals considering routing. Computer-Aided Civil and Infrastructure Engineering. https://doi.org/10.1111/j.1467-8667.2006.00468.x
- Teodorović, D. (2003). Transport modeling by multi-agent systems: A swarm intelligence approach. Transportation Planning and Technology. https://doi.org/10.1080/0308106032000154593
- Timmis, J., Neal, M., & Hunt, J. (2000). An artificial immune system for data analysis. BioSystems. https://doi.org/10.1016/S0303-2647(99)00092-1
- Trabelsi, B., Elkosantini, S., & Darmoul, S. (2012). Traffic Control at Intersections Using Artificial Immune System Approach. 9th International Conference of Modeling, Optimization and Simulation - MOSIM'12.

References

- Transportation Research Board. (2007). Artificial Intelligence in Transportation. Transportation Research Circular. https://doi.org/ISSN 0097-8515
- Ulusoy, G., Sivrikaya-Şerifoğlu, F., & Bilge, Ü. (1997). A genetic algorithm approach to the simultaneous scheduling of machines and automated guided vehicles. Computers and Operations Research. https://doi.org/10.1016/S0305-0548(96)00061-5
- Vlahogianni, E. I., Park, B. B., & Van Lint, J. W. C. (2015). Big data in transportation and traffic engineering. Transportation Research Part C: Emerging Technologies. https://doi.org/10.1016/j.trc.2015.08.006
- Vovsha, P., Petersen, E., & Donnelly, R. (2007). Impact of Intrahousehold Interactions on Individual Daily Activity-Travel Patterns. Transportation Research Record: Journal of the Transportation Research Board. https://doi.org/10.3141/1898-11
- Xu, T., Wei, H., & Wang, Z. De. (2009). Study on continuous network design problem using simulated annealing and genetic algorithm. Expert Systems with Applications. https://doi.org/10.1016/j.eswa.2008.01.071
- Yagi, S., & Mohammadian, A. (2010). An activity-based microsimulation model of travel demand in the Jakarta metropolitan area. Journal of Choice Modelling. https://doi.org/10.1016/S1755-5345(13)70028-9
- Yin, W., Murray-Tuite, P., Ukkusuri, S. V., & Gladwin, H. (2014). An agent-based modeling system for travel demand simulation for hurricane evacuation. Transportation Research Part C: Emerging Technologies. https://doi.org/10.1016/j.trc.2014.02.015
- Zhang, S., Lee, C. K. M., Chan, H. K., Choy, K. L., & Wu, Z. (2015). Swarm intelligence applied in green logistics: A literature review. Engineering Applications of Artificial Intelligence. https://doi.org/10.1016/j.engappai.2014.09.007

THANK YOU!