TRANSPORT FINDINGS

Long-Distance Person Travel: A Cluster-Based Approach

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Keywords: cluster analysis, fuzzy c-means, k-means, agglomerative hierarchical clustering, travel behaviour, travel modelling, long-distance person travel

Transport Findings

Many long-distance person trips (LDPT) modelling efforts fail to accurately represent trips using traditional segmentation approaches. Thus, a clustering approach was used herein to segment an intra-provincial trips data set. The trips' segments found were short economical getaways (36%), same-day shopping (16%), personal business (14%), visiting friends/relatives (10%), business/casino trips (10%), young adults playing team sports (6%), same-day trips of snow/festival loving young families with kids (3%), costly cottage/camping trips (3%), seniors with medical appointments (2%), and multiple city visitors (1%). The existence of clusters and associated activities shows what segmentation approaches modern models should follow.

The analysis of travel demand often includes the partitioning of the demand into "market segments" seeking to separate these influences into groups. As demonstrated in (Larse 2010; Travel Demand Modelling 2016; Limtanakool, Dijst, and Schwanen 2006; Bhat 1997b; Koppelman and Sethi 2000; Mandel, Gaudry, and Rothengatter 1997; Ben-Akiva and Lerman 1987; Wardman, Toner, and Whelan 1997; LaMondia, Bhat, and Hensher 2008; Carlsson 1999; Hensher 1991; Morrison and Winston 1985; Hassanvand 2020), the development of such models includes substantial effort that encompasses enormous revalidation work, which has been reduced with the aid of advanced computer technology. However, there still exists a gap in model design that arise from failure to segment markets.

This paper defines travel alternatives made by market segments with the aim of optimizing the selection of descriptive variables and strengthening the explanatory power of the model. Nearly all long-distance person trips (LDPT) models (Federal Highway Administration 2015; Golob 2001; Kizielewicz et al. 2017; Bhat 1997a; Golob and Hensher 1998; Badoe and Miller 1998; Lieberman et al. 2001) developed in various countries are based not on empirical procedures but rather by educated guesses to describe the travel market variables. This research transforms the approach to traditional segmentations using computer science approaches for network-based data that stem from fuzzy logic (Zadeh 1965). Such approaches are based on grouping of data points by examining their proximity (e.g. Euclidean distance) to one another. This is essential as LDPT is not merely the longer version of short-distance daily trips. While fuzzy-neuro models have been used in transit and some short-distance models (Kumar, Sarkar, and Madhu 2013; Sarkar 2012; Tharwat 2014; Roxas 2016; Yaldi et al, n.d.; Gite 2013), they have not been used in LDPT – excluding goods movement, trucking, or air travel.

Table 1: Clustering Steps

Clustering Steps	Description
Step 1	Select an initial partition K (C1,...,Ck)
Step 2	Calculate centroid $w_i = \left(\frac{1}{k}\right) \sum_{j=1}^{ki} (w_{ij})$ for i = 1,...,k
Step 3.1	For each w_i reassign w_i to its closes centroid C_t if $\ w_i - w_t\ \leq \ w_i - w_j\ $ for all $j= 1,...,k, j \neq t$
Step 3.2	Recalculate centroids for clusters C_s and C_t
Step 4	In cluster membership is stabalized then stop or else go to Step 3

Table 1: Clustering Steps

METHODS AND DATA

Clustering is a statistical tool used in pattern recognition and machine learning to find similar groups in seemingly dissimilar network-based datasets (e.g. transport data). Objects in a cluster/class share many characteristics but are very dissimilar to objects not belonging to that particular cluster (Punj and Stewart 1983). In most of the classification works (Milligan 1996; Posse 1998; Everitt, Landau, and Leese 2001), considerable number of algorithms belong to two major types of clustering used here namely Hierarchical and Partitional. The former is based on finding clusters hierarchy using a criterion and producing a dendrogram. The latter is partitioning the data based on minimization of an objective function such as the squared error function (Kaufman and Rousseeuw 1990; Bezdek 1974):

$$J = \sum_{j=1}^k \sum_{i=1}^n \|x_i^{(j)} - c_j\|^2 \quad (1)$$

Where $\|x_i^{(j)} - c_j\|^2$ is the distance between a data item $x_i^{(j)}$ and a centre point c_j .

One type of partitional clustering, with steps shown in Table 1, is called the k-means approach as a specific form of the more general fuzzy c-means clustering that minimizes a similar objective function [34]:

The uniqueness of this work lies partly in the essential three-step cluster validity checks which are often ignored in many clustering themed studies (Dunn 1974; Zaki and Meira, Jr 2014):

1. Cluster tendency checks: which is a measure of clusterability of a data set considering that algorithms such as k-mean unquestioningly find some clusters in a data set regardless. Thus, to ensure the data is actually clusterable, one must examine it for its clustering tendency using indices such as the Hopkins statistics prior to any clustering practices.

2. Cluster stability checks: is the practice of clustering randomly generated data sets out of the original data and data belonging to other years/locations in order to examine if the resulting clusters are persistent and show up each time. Also, clustering the data set using fuzzy c-means provides an additional check on the existence/lack of potential outliers and acts as a precautionary measure against model-dependency of results.
3. Cluster validity: consists of three tests namely External (one-way ANOVA, Post-hoc Bonferroni, and Logistic Regression), Internal (Beta-CV index), and Relative (Elbow method). Other tests include variables' correlation checks, F-tests, Grubb's test of outliers, Ward's (AHC) dendrogram analyses and stopping rules comparison of a large Duda-Hart $Je(2)/Je(1)$ index with a small Pseudo T-tests and a large Calinski-Harabasz Pseudo-F indices for detection of number of clusters (Everitt, Landau, and Leese 2001).

The publicly available standardized and weighted 2017 Travel Survey of Residents of Canada (TSRC) data set – including 14064 Province of Alberta (AB) residents, 4167 AB to AB trips, and 6128 nights travelled – is examined and compared with 2016 and 2015 data. TSRC is a supplement of the Canadian Labour Force Survey (LFS) (Statistics Canada 2017b, 2017a) after which TSRC questions are asked of a random 18+ household (HH) member regarding any one-way 40+ km trips from home finished in the previous month (same-day/overnight) plus any overnight trips ended two months before regardless of distance. [Figure 1](#) shows trip counts by distance/purpose followed by variables' list in [Table 2](#). Analysis is based on 100 variables with minimal correlations from socio-demographic factors to places visited and 37 different activities divided into same-day/overnight.

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[Table 3](#) describes 10 clusters found in the 2017 data set followed by [Figure 2](#) which is a 3D representation of clusters' center points across some of the most important dimensions (for brevity). [Figure 3](#) represents a dendrogram of classes hierarchy found through (AHC) clustering.

Examinations revealed the data possess a natural structure with 10 clusters at 68% confidence level. Such results are consistent with other literature findings for LD trips (Future Foundation 2015; Birley and Westhead 1990; Mooi and Sarstedt 2011). For example, trips done for pleasure have consistently been found to belong to mostly the top two categories of LDPT. The second largest cluster is representative of individual adults from the same HH who travel in smaller groups with no kids. Their purpose is mainly same-day trips of shopping with moderate levels of spending with activities such as walking. This finding is novel and could be a characteristic of the Province of Alberta, in that malls and shopping centres such as Banff, Lake Louise, West Edmonton

Figure 1: Count of Trips by Distance and Canadian Nights Away for 2017 (TSRC) 4167 (AB) to (AB) Trips

mall, or other shopping avenues are also long-distance traveller attractors. The existence of such clusters demonstrates how traditional LDPT trips segmentation through “guessing variables and rechecking” are obsolete and would need to be enhanced using comprehensive clustering approaches targeted for network-based data to better represent the overall LDPT market while relying less on conjecture and assumptions.

Submitted: September 20, 2020, Accepted: September 20, 2020

#	Name	Label	Type	Question
1	TR_G08	Household members 18 or older who went on the trip - Capped	continuous	Number of household members 18 years of age and over on trip - Capped.
2	TR_D11	Number of identical trips - capped	continuous	How many? (Identical trips).
3	TS_TOTAL	Total amount spent on all spending	continuous	Total amount spent on all spending, including amount extracted from travel packages.
4	DIST2	Distance of trip - farthest location	continuous	one way distance in km travelled to the farthest destination location
5	TRIP_CNT	Total number of trip records	continuous	Total number of trip records
6	TP_D01	Total number of people in travel party - Grouped	continuous	Total number of people in travel party - Grouped.
7	T_G0802	Household members who went on the trip - Capped	continuous	Household members who went on trip- Capped.
8	TP_G02	Household members under 18 who went on the trip - Capped	continuous	Number of household members under 18 years of age on trip - Capped.
9	AGE_GR2	Age group of the respondent - Grouped	discrete	age of the 18+ random respondent to TSRC
10	SEX	Sex of respondent	discrete	sex of the 18+ random respondent to TSRC
11	EDLEVGR	Education level of respondent - Grouped	discrete	education level of the 18+ random respondent to TSRC
12	LFSSTATG	Labour force status - Grouped	discrete	employed or unemployed status of the 18+ random respondent to TSRC
13	MDDPLFL	Province of trip Destination	discrete	residency Province of the 18+ random respondent to TSRC
14	INCOMGR2	Household income - 4 groups	discrete	Household income - 4 groups.
15	CANNITE	Total number of nights in Canada during the trip	discrete	Total number of nights on the trip spent in Canada.
16	REFYEAR	Reference year	discrete	Reference year
17	REFMONTH	Reference month	discrete	Reference month
18	TRIPTYPE	Type of trip	discrete	Type of trip.
19	MRDTRIP3	Main reason for the trip - 7 categories	discrete	Main reason for the trip - 7 categories.
20	ORCPROVT	Province of trip origin	discrete	Province of trip origin.
21	TMDTYPE2	Main mode of transportation used on the trip	discrete	Main mode of transportation used on the trip.
22	AT_Q01X	Activity - Attend an aboriginal event	discrete	On this trip did you attend an aboriginal event (pow wow, performance, other)?
23	AT_Q01H	Activity - Go to a beach	discrete	On this trip did you go to a beach?
24	AT_Q01J	Activity - Go boating	discrete	On this trip did you go boating?
25	AT_Q01G	Activity - Go wildlife viewing or bird watching	discrete	On this trip did you go wildlife viewing or bird watching?
26	AT_Q01I	Activity - Go camping	discrete	On this trip did you go camping?
27	AT_Q01O	Activity - Go canoeing or kayaking	discrete	On this trip did you go canoeing or kayaking?
28	AT_Q01P	Activity - Go to a casino	discrete	On this trip did you go to a casino?
29	AT_Q01N	Activity - Go cycling	discrete	On this trip did you go cycling?
30	AT_Q01Q	Activity - Attend a festival or fair	discrete	On this trip did you go to a fair or attend a festival?
31	AT_Q01K	Activity - Go fishing	discrete	On this trip did you go fishing?
32	AT_Q01M	Activity - Go golfing	discrete	On this trip did you go golfing?
33	AT_Q01F	Activity - Go hiking or backpacking	discrete	On this trip did you go backpacking or hiking?
34	AT_Q01B	Activity - Visit a historic site	discrete	On this trip did you visit a historic site?
35	AT_Q01L	Activity - Go hunting	discrete	On this trip did you go hunting?
36	AT_Q01C	Activity - Visit a museum or art gallery	discrete	On this trip did you go to an art gallery or visit a museum?
37	AT_Q01A	Activity - Visit a national/ provincial or nature park	discrete	On this trip did provincial or nature park?
38	AT_Q01D	Activity - Attend a performance	discrete	On this trip did you attend a performance such as a play or concert?
39	AT_Q01V	Activity - Go cross country skiing or snowshoeing	discrete	On this trip did you go cross country skiing or snowshoeing?
40	AT_Q01W	Activity - Go snowmobiling	discrete	On this trip did you go snowmobiling?
41	AT_Q01E	Activity - Attend a sports event as a spectator	discrete	On this trip did you attend a sports event as a spectator?
42	AT_Q01T	Activity - Play individual or team sports	discrete	On this trip did you play individual or team sports?
43	AT_Q01R	Activity - Visit a theme or amusement park	discrete	On this trip did you visit a theme or amusement park?
44	AT_Q01S	Activity - Visit a zoo or aquarium	discrete	On this trip did you visit a zoo or aquarium?
45	AT_Q01Z	Activity - Shop (include all markets)	discrete	On this trip did you go shopping (include all markets)?
46	AT_Q01U	Activity - Go downhill skiing or snowboarding	discrete	On this trip did you go downhill skiing or snowboarding?
47	AT_Q01AA	Activity - Attend a business/ other meeting	discrete	On this trip did you attend a business/ other meeting/conference/seminar?
48	AT_Q01AB	Activity - Go to a medical/ dental appointment	discrete	On this trip did you medical/dental appointments?
49	AT_Q01AC	Activity - Sightsee	discrete	On this trip did you go for sightseeing?
50	AT_Q01AD	Activity - Go to the movies	discrete	On this trip did you go to movies?
51	AT_Q01AE	Activity - Dine out/go to restaurant/bar/club	discrete	On this trip did you restaurant/bar/club?
52	AT_Q01AF	Activity - ATV (quad, 4X4)	discrete	ATV (quad, 4X4)?
53	AT_Q01AG	Activity - Did not do any activities	discrete	no activities?
54	AT_Q01AH	Activity - Other activity	discrete	other activities?
55	AT_Q02	Activity - Most important - Same day trip	discrete	most important activity for same-day trips?
56	AT_Q01Y	Activity - Visit friends or family	discrete	On this trip did you visit friends or family (include wedding, graduation, anniversaries, family reunion or dinner, babysitting, etc.)?

Table 2: List of Variables

Cluster/Class Title	Description	Percentage of Total
Short Economical Getaways	Represents trips (with frequency of two) made by most likely University educated adults in smaller groups (mostly one traveller or potentially only one other partner) not from the same HH going on short (same-day) getaways of about 100 km in private cars for pleasure purposes and having low spending amounts (less than \$100) with potential overnight activities such as skiing and same-day activities such as cycling, hiking, and visiting parks.	36
Same-day Shopping	Trips (with frequency of two) consisting of smaller groups (two travellers) of adults from the same HH travelling with no kids on short trips (same-day) with moderate levels of spending (about \$150) and travelling shorter distances (about 100 km) in mostly private cars.	17
Personal Business Trips	Represents trips (with frequency of two) characterized by individual older adults travelling mostly alone or with only one other traveller for longer distances (about 300 km) by air and taxi for long number of nights (about one week) with no kids and moderate spending (about \$250) and having "other" types of activities.	14
VFR Trips	Trips (with frequency of one) consisting of larger groups (about 4) mostly from the same HH with older kids travelling shorter distances (about 100 km) on trips of about three nights in private cars with moderate spending (about \$150) for the purpose of visiting friends and relatives and having not many activities.	11
Business/casino Trips	Represents trips (with frequency of one) consisting of younger adults (with mostly low incomes in groups of about two) travelling by air, bus, and/or rental cars for longer distances (over 250 km) and about two nights away and spending around \$200 visiting casinos while on the trip, playing sports, skiing, or being a sports spectator most likely alongside business partners. The fact that such trips are mostly taken by young adults confirms the findings of [38] stating that 45% of most business trips are taken by Millennials and younger adults.	10
Young Families with Children going to Seasonal Events	Trips (with frequency of two) consisting of younger parents with lower levels of income from the same HH (with groups of three travellers) going on shorter (about 100 km) low budget trips in private cars (under \$100) for about two nights with kids and participating in snow related activities in the winter time and visiting zoo, parks, and festivals in the warmer months. These results confirm the findings of [39] that states events have now become one of the main attractors of travellers as many seek a more planned trip as well as a cultural experience in the process.	3
Team Sport Players	Represents trips (with frequency of one) consisting of non-adult members (in groups of three or more) from the same household with high school education and low incomes going on overnight trips (about a week) in buses and most likely participating in team sports and spending about \$200 having travelled longer distances of about 300 kms.	3
Costly Cottage/Camping trips	Represents trips (with frequency of two) consisting of mixed generation of adults in groups of two from different HHs with high levels of spending (over \$400) and lower kilometers travelled (about 150 km) on cottage, camping, or boating trips of about two nights in private cars.	3
Seniors with Medical Appointments	Trips (with frequency of one) consisting of low income low educated seniors travelling in groups of about three or in pairs on same-day or overnight shorter trips (about 100 km) with private cars or buses with light levels of spending (about \$80) and having no or little activities such as shopping and going to medical appointments.	3
High Educated Multiple City Visitors	This group represents high educated outdoorsy visitors (in groups of three or more) on higher budget trips (about \$500) involving visiting more than two locations along the way having travelled about 200 km and spent two nights using travel modes such as RVs and private cars.	2

Table 3: Clusters Found in the 2017 (TSRC) (AB) to (AB) Trips at 68% Confidence Level

Figure 2: 3D Representation of 10 Clusters Across a few Key Dimensions: Household (HH) Members on the Trip, Travelling Group Size, Total Nights Away from home while on Trip, One-way Distance from Home in km, Trips Frequency, Total Amount of Spending while on Trip in 2017 \$CAD

Figure 3: 2017 (TSRC) (AB) to (AB) Trips (AHC) Ward's Dendrogram

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REFERENCES

- Badoe, Daniel A., and Eric J. Miller. 1998. "An Automatic Segmentation Procedure for Studying Variations in Mode Choice Behaviour." *Journal of Advanced Transportation* 32 (2): 190–215. <https://doi.org/10.1002/atr.5670320205>.
- Ben-Akiva, M., and S. Lerman. 1987. *Discrete Choice Analysis: Theory and Application to Travel Demand*. Cambridge, MA: MIT Press.
- Bezdek, J. C. 1974. "Numerical Taxonomy with Fuzzy Sets." *Journal of Mathematical Biology* 1 (1): 57–71. <https://doi.org/10.1007/bf02339490>.
- Bhat, C. R. 1997a. "An Endogenous Segmentation Mode Choice Model with an Application to Intercity Travel." *Transportation Science* 31 (1): 34–48. <https://doi.org/10.1287/trsc.31.1.34>.
- . 1997b. "Covariance Heterogeneity in Nested Logit Models: Econometric Structure and Application to Intercity Travel." *Transportation Research Part B: Methodological* 31 (1): 11–21. [https://doi.org/10.1016/s0191-2615\(96\)00018-5](https://doi.org/10.1016/s0191-2615(96)00018-5).
- Birley, S., and P. Westhead. 1990. "Growth and Performance Contrasts between 'Types' of Small Firms." *Strategic Management Journal* 11 (7): 535–57.
- Carlsson, F. 1999. "Private vs. Business and Rail vs. Air Passengers: Willingness to Pay for Transport Attributes." In *Department of Economics of Goteborg University, Working Paper in Economics No, 14*. <https://gupea.ub.gu.se/handle/2077/2679>.
- Dunn, J. C. 1974. "Some Recent Investigations of a New Fuzzy Partitioning Algorithm and Its Application to Pattern Classification Problems." *Journal of Cybernetics* 4 (2): 1–15. <https://doi.org/10.1080/01969727408546062>.
- Everitt, B. S., S. Landau, and M. Leese. 2001. *Cluster Analysis*. 4th ed. Arnold, London.
- Federal Highway Administration. 2015. "Foundational Knowledge to Support a Long-Distance Passenger Travel Demand Modeling Framework Part A: Final Report." <http://rsginc.com/files/publications/Long%20Distance%20Model%20Framework%20Final%20Report.pdf>.
- Future Foundation. 2015. "Understanding Tomorrow's Traveller." <http://www.amadeus.com/web/binaries/blobs/378/139/amadeus-future-traveller-tribes-2030-report.pdf>.
- Gite, Akhil V. 2013. "ANFIS Controller and Its Application." *International Journal of Engineering Research and Technology* 2 (ue 2).
- Golob, T. F. 2001. "Joint Models of Attitudes and Behavior in Evaluation of the San Diego I-15 Congestion Pricing Project." *Transportation Research Part A: Policy and Practice* 35 (6): 495–514. [https://doi.org/10.1016/s0965-8564\(00\)00004-5](https://doi.org/10.1016/s0965-8564(00)00004-5).
- Golob, T. F., and D. A. Hensher. 1998. "Greenhouse Gas Emissions and Australian Commuters' Attitudes and Behavior Concerning Abatement Policies and Personal Involvement." *Transportation Research Part D: Transport and Environment* 3 (1): 1–18. [https://doi.org/10.1016/s1361-9209\(97\)00006-0](https://doi.org/10.1016/s1361-9209(97)00006-0).
- Hassanvand, M. 2020. "Adjusting Logit Model Estimation Results Obtained with Stated Preference Data." *International Journal of Scientific & Engineering Research* Volume 11 (June 6). <https://www.ijser.org/onlineResearchPaperViewer.aspx?Adjusting-Logit-Model-Estimation-Results-Obtained-with-Stated-Preference-Data.pdf>.
- Hensher, D.A. 1991. "Efficient Estimation of Hierarchical Logit Mode Choice Models." *Proceedings of the Japanese Society of Civil Engineering* 425 (IV–14): 17–28. <http://library.jsce.or.jp/jsce/open/00037/425/425-120617.pdf>.

- Kaufman, Leonard, and Peter J. Rousseeuw, eds. 1990. *Finding Groups in Data. Wiley Series in Probability and Statistics*. New York: John Wiley & Sons, Inc. <https://doi.org/10.1002/9780470316801>.
- Kizielewicz, Joanna, Anntti Haahti, Tihomir Luković, and Daniela Gračan. 2017. "The Segmentation of the Demand for Ferry Travel - a Case Study of Stena Line." *Economic Research-Ekonomska Istraživanja* 30 (1): 1003–20. <https://doi.org/10.1080/1331677x.2017.1314789>.
- Koppelman, F.S., and V. Sethi. 2000. "Incorporating Complex Substitution Patterns and Variance Scaling in Long-Distance Travel Choice Behavior." Paper presented at the 9th International Association on Travel Behavior Research Conference, July 2-7, 2000, Goldcoast, Queensland.
- Kumar, Mukesh, Pradip Sarkar, and Errampalli Madhu. 2013. "Development Fuzzy Logic-Based Model Mode Choice Model Considering Various Public Transport Policy." *IJTTE* 3 (4): 408–25. [https://doi.org/10.7708/ijtte.2013.3\(4\).05](https://doi.org/10.7708/ijtte.2013.3(4).05).
- LaMondia, J., C. Bhat, and D. Hensher. 2008. "An Annual Time Use Model for Domestic Vacation Travel." *Journal of Choice Modeling* 1 (1): 70–97. <http://www.jocm.org.uk/index.php/JOCM/article/viewFile/38/15>.
- Larse, Nynne. 2010. *Market Segmentation - A Framework for Determining the Right Target Customers*. Published Thesis. Aarhus School of Business.
- Lieberman, William, Dave Schumacher, Alan Hoffman, and Christopher Wornum. 2001. "Creating a New Century of Transit Opportunity: Strategic Planning for Transit." *Transportation Research Record: Journal of the Transportation Research Board* 1747 (1): 60–67. <https://doi.org/10.3141/1747-08>.
- Limtanakool, N., M. Dijst, and T. Schwanen. 2006. "The Influence of Socioeconomic Characteristics, Land Use and Travel Time Considerations on Mode Choice for Medium- and Longer-Distance Trips." *Journal of Transport Geography* 14 (5): 327–41. <https://doi.org/10.1016/j.jtrangeo.2005.06.004>.
- Mandel, B., M. Gaudry, and W. Rothengatter. 1997. "A Disaggregate Box-Cox Logit Mode Choice Model of Intercity Passenger Travel in Germany and Its Implications for High-Speed Rail Demand Forecasts." *The Annals of Regional Science* 31 (2): 99–120. <https://doi.org/10.1007/s001680050041>.
- Milligan, Glenn W. 1996. "Clustering Validation: Results and Implications for Applied Analyses." In *Clustering and Classification*, 341–75. Singapore: World Scientific. https://doi.org/10.1142/9789812832153_0010.
- Mooi, E., and M. Sarstedt. 2011. "A Concise Guide to Market Research Chapter 8." Springer-Verlag Berlin Heidelberg.
- Morrison, S.A., and C. Winston. 1985. "An Econometric Analysis of the Demand for Intercity Passenger Transportation." In *Research in Transportation Economics: A Research Annual*, edited by T.E. Keeler, 2:213-237,. Greenwich, Connecticut: JAI Press.
- Posse, C. 1998. "Hierarchical Model-Based Clustering for Large Data Sets." Technical report, University of Minnesota, School of Statistics.
- Punj, Girish, and David W. Stewart. 1983. "Cluster Analysis in Marketing Research: Review and Suggestions for Application." *Journal of Marketing Research* 20 (2): 134–48. <https://doi.org/10.1177/002224378302000204>.
- Roxas, Nicannor R. 2016. "Application of Artificial Neural Network to Trip Attraction of Condominiums in Metro Manila." In *Proceedings of the 23rd Annual Conference of the Transportation Science Society of the Philippines*. Quezon City, Philippines: TSSP.

Sarkar, Amrita. 2012. "Application of Fuzzy Logic in Transport Planning." *International Journal on Soft Computing (IJSC)* 3 (2): 1–21. <https://doi.org/10.5121/ijsc.2012.3201>.

Statistics Canada. 2017a. "Labour Force Survey." <https://www150.statcan.gc.ca/n1/daily-quotidien/180105/dq180105a-eng.htm>.

———. 2017b. "Travel Survey of Residents of Canada." <https://www.statcan.gc.ca/eng/survey/household/3810>.

Tharwat, O.S. 2014. "Identification of Uncertain Nonlinear MIMO Spacecraft Systems Using Coactive Neuro Fuzzy Inference System (CANFIS)." *International Journal of Control, Automation, and Systems* Vol. 3 (2).

Travel Demand Modelling. 2016. "Transport and Infrastructure Council, National Guidelines for Transport System Management in Australia." https://ngtsguidelines.files.wordpress.com/2014/08/ngtsgm2016-t1_travel_demand_modelling.pdf.

Wardman, M., J. P. Toner, and G. A. Whelan. 1997. "Interactions between Rail and Car in the Inter-Urban Leisure Travel Market in Great Britain." *Journal of Transport Economics and Policy* 31 (2): 163–81.

Yaldi et al. n.d. "Developing a Fuzzy-Neuro Model for Travel Demand Modelling."

Zadeh, L.A. 1965. "Fuzzy Sets." *Information and Control* 8 (3): 338–53. [https://doi.org/10.1016/s0019-9958\(65\)90241-x](https://doi.org/10.1016/s0019-9958(65)90241-x).

Zaki, Mohammed J., and Wagner Meira, Jr. 2014. *Data Mining and Analysis: Fundamental Concepts and Algorithms*. New York, NY: Cambridge University Press. <https://doi.org/10.1017/cbo9780511810114>.