

The Electrification of Canadian Urban Bus Transit: An Analysis of Providers' Perspectives

Moataz Mahmoud ^{*1}, Mark Ferguson ², Pavlos Kanaroglou ³

¹ *Post-Doctoral Research Fellow, McMaster Institute for Transportation and Logistics, McMaster University, Hamilton, ON, L8S 4K1, Canada, mmohame@mcmaster.ca*

² *Senior Research Associate, McMaster Institute for Transportation and Logistics, McMaster University, Hamilton, ON, L8S 4K1, Canada, fergumr@mcmaster.ca*

³ *Professor, School of Geography & Earth Sciences, McMaster University, Hamilton, ON, L8S 4K1, Canada, pavlos@mcmaster.ca*

Summary

This study investigates the perspectives of transit providers regarding the implementation of electric buses in Canadian transit. It is evident that while environmental, operational, and economic features of electric buses are competitive with their diesel counterparts, current market share tells a different story. The electric bus has a very small share in the transit market, which is mainly attributed to its limitation in satisfying day-to-day operational demands. This study aims at understanding the decision making process for fleet management strategy (operation & acquisition) based on the perspectives of service providers to identify key barriers that hinder the adoption of electric buses in Canada. In total, 11 in-depth interviews were conducted across Canada, covering jurisdictions that represent 63.19% of Canadian bus ridership. A grounded theory analytical approach is employed that utilizes participants' perspective/experience to construct a theory. The findings highlight that, at the present time, there is little desire from service providers to implement electric bus technology in a daily full-network operation. This is attributed to the sensitivity of electric buses to the operation context in various respects. The current risk-averse decision-making environment is also highlighted as a reason for not considering the electric bus as an economical and operationally capable powertrain technology. Standardization, technology anxiety, and full network operational feasibility were also identified as roadblocks for the electrification of bus transit. In this respect, the study concludes with the development of a detailed portrait for a feasible utilization of EV technologies in transit to guide future research.

Keywords: Electric bus, Public Transport, Transit provider

1. Introduction

Public transit is always considered a cornerstone to reduce transport social exclusion as it offers a cheaper mobility choice. It is also an indicator of economic development and welfare in many countries [1]. Increasingly, public transit is facing a remarkable transformation not only from the technological perspective, but also in relation to societal and ecological impacts. Indications of attitudinal shift towards shared mobility, smart commutes, and automated mobility are palpable. There is declining desire to own a private car as a means of transport [2, 3]. Public transit is expected to play a major role in the future of personal mobility. That

being said, transportation currently contributes 22% of global GHG emissions, a share which is often flagged as a target for potential emissions reduction [4].

On the other hand, electricity is a clean source of energy that provides a better alternative to finite fossil fuels [5]. Although there are valid concerns about electricity generation methods and its sensitivity to increase/decrease GHG emissions at the macro level, electricity is arguably the only source of energy with the promise of net-zero emissions [3, 6, 7]. At the micro level, electricity offers zero local emissions, and better air quality. The electrification of transport, therefore, is receiving considerable attention from academics and policy makers [2, 4, 6-8]. Electric bus transit, in particular, is considered a suitable target to considerably decarbonize transport. The nature of bus transit operation, with fixed routes and timely schedules, offers a suitable setting to utilize electric powertrain technology [2, 4].

The adoption path of the electric bus in transit has been examined via several domains of research. Technology review [9-11], battery technology [12, 13], life cycle cost models [2, 7], environmental assessment [14-17], market demands [18], and operational feasibility [4, 19, 20] have been prominent research domains in the electric bus literature. Although these attempts provide sound contributions, additional aspects that significantly affect the electrification of bus transit are surprisingly yet to be investigated. Most notable is the lack of research that investigates the willingness, or lack thereof, of service providers to adopt electric bus technology. In this respect, two fundamental aspects are not fully addressed in the literature; firstly, transit providers are at the forefront of operating the electric bus, and understanding their operational, and organizational demands is imperative [4]. Secondly, almost all models are based on bus-to-bus comparison and/or a small fleet (2-4 buses) with controlled/selected operational conditions, which does not reflect the varied operational demands that service providers encounter on a daily basis [21].

This study provides evidence on the perspectives of transit providers in Canada as it relates to the implementation of the electric bus in the transit context. The study aims to identify key factors that hinder the widespread use of electric buses in transit. It provides a blueprint of a feasible path toward adoption of the electric bus in Canadian transit. To the best of our knowledge, there has been no previous study that investigated the implementation of the electric bus from a transit provider perspective.

2. Study Context

In Canada, the bus transit delivery chain involves five key players that include the federal government, provincial governments, municipalities, and Transit Agencies [22]. Mainly, municipalities are responsible for delivering bus transit services, which are partly self-funded through fares and local taxes. Transit agencies are established to fulfill transit demands in some specific areas. They are created as a link between regional municipalities and provinces, and funded through municipalities and provincial governments, as well as through federal grants in special cases. In contrast, federal and provincial governments generally do not directly operate transit services. They however, provide funds/subsidies for municipalities in different forms.

With respect to electric bus operation, there is no specific policy dedicated to enforce the implementation of the any electric bus in transit. Policies are geared towards emissions reduction in general. However, few electric bus demonstration projects are currently operational in Canada. In the province of Manitoba, Winnipeg transit operates an electric bus powered by lithium-ion batteries on an airport route (route 20 Academy-Watt). Societe de Transport de Montreal (STM) will operate four electric buses in a Montreal demonstration project, which is sponsored by the provincial government of Quebec. In addition, three mini electric buses (5.3m) have been in operation in Quebec since 2005 [23].

3. Data and Participants

A total of 11 transit providers participated in the study, out of a larger list that were contacted, and in-depth interviews were conducted during March-June 2015. These transit providers are: Toronto (Toronto Transit

Commission, TTC), Hamilton (Hamilton Street Railway, HSR), Windsor (Windsor Transit), Region of Waterloo (Grand River Transit, GRT), Halifax (Metro Transit), Kentville (Kings Transit), Fredericton (Fredericton Transit), Winnipeg (Winnipeg Transit), Calgary (Calgary Transit), Ottawa (OC Transpo), and Montreal (Societe de Transport de Montreal, STM). These organizations represent 63.19% of the Canadian transit ridership across six provinces. Table 1 highlights the diversity in operational capacity, fleet characteristics and market size within the sample and that the organizations provide a good cross-section of the Canadian transit context.

Table 1. Participants information

Transit Provider	City	Province	Population Served*	% of National Ridership	Fleet Size*	Average Fleet Age*	Total Traveled KM*
TTC	Toronto	Ontario	2,808,503	26.40%	1,869	7.4	120,915,443
HSR	Hamilton	Ontario	490,000	1.10%	221	6.6	13,696,705
Windsor Transit	Windsor	Ontario	210,891	0.31%	112	10.1	5,077,299
GRT	Region of Waterloo	Ontario	434,437	1.07%	235	6.3	14,006,366
Metro Transit	Halifax	Nova Scotia	308,084	0.95%	312	7.3	15,451,523
Kings Transit	Kentville	Nova Scotia	42,500	0.02%	14	5.8	630,000
Fredericton Transit	Fredericton	New Brunswick	50,000	0.08%	27	9.0	1,071,380
Winnipeg Transit	Winnipeg	Manitoba	675,300	2.46%	583	9.6	26,172,798
Calgary Transit	Calgary	Alberta	1,195,194	5.44%	1,053	7.3	49,354,009
OC Transpo	Ottawa	Ontario	857,890	4.79%	936	5.5	48,326,802
STM	Montreal	Quebec	1,959,987	20.56%	1,729	5.8	72,548,985

* Data are based on [24]

Participants included those of directors, fleet/operation managers, maintenance managers, and planning managers. One participant represented each transit property, and prior to the interview, a detailed information package was sent to participants that included consent forms, interview themes, and subject information sheet. On average, interviews lasted one hour and 12 minutes.

The data analysis follows the typical grounded theory analytical approach advocated by Glaser and Strauss [25]. The analysis is carried out by two researchers independently, and a cross-comparison of materials (codes, notes, and categories) showed similar results, which confirms that personal intervention during data interpretation is indeed eliminated. The analysis comprehensively identifies the dimensions (political, operational, technological, and attitudinal) that constitute a feasible implementation of electric bus in the Canadian urban transit context.

4. Findings

Interview participants raised a wide range of factors that govern the implementation of the electric bus in the transit context. The analysis yielded 55 distinct themes that are sorted into 16 subcategories, and further refined into four categories as detailed in Table 2. The following subsections detail the perspectives of transit providers towards these subcategories.

Table 2. Interview results

Categories	Subcategories
Attitude towards the electric bus	General attitude towards electric technology The “Guinea Pig” syndrome Technology Anxiety Lack of operational data Risk and safety concerns
Operational feasibility of the electric bus	Operational availability Network optimization Human resources Total Cost of Ownership Standardization of electric bus technology
Decision-making & fleet management strategy	Decision making Fleet management strategy Manufacturers and the U.S. influence
Developing a business case; the way forward	Top-down approach & political intervention Implementation criteria & regulatory environment

4.1 Attitude towards electric bus

In general, a positive attitude towards electric bus technology was evident in the data. It is considered a viable technology and a good powertrain choice that fits the nature of transit operation. Several advantages of electric vehicle technology are identified, most notably is the low level of noise and vibration associated with the electric bus. In addition, the comfort of an electric bus, with no shifting gears, is identified as a good feature for a more appealing transit service.

“It’s there. When I first heard about it, I thought Nah, it’s going nowhere, but you know what, they made a believer out of me because I can’t believe the leaps that have been made in the last couple of years, the technology is just pretty” – HSR, Hamilton.

Overall, the positive orientation towards electric bus technology by service providers seemed always associated with future implementation only. It is evident in the data that transit providers consider electric bus a viable *future* technology but not for implementation at the present time. This perception is attributed to five aspects.

- **The “Guinea Pig” syndrome**

All participants stated that it is risky to be the first providers with new technology and that some other jurisdiction should play the role of “guinea pig”.

“I am worried about being a guinea pig and getting a system in that two years later it’s out of date” – Fredericton Transit, Fredericton.

- **Technology anxiety**

The term refers to concerns that current electric powertrain technology will soon be obsolete. Rapid technological advancement in several components (i.e. range, charge time, and batteries) is identified as a major barrier for adopting electric bus in transit.

“Especially with that kind of technology, is going to make sure that it doesn’t go obsolete or that we don’t have to... like 5 years down the road the technology advances so much that now the system is new... you may as well just dump the bus” – Metro Transit, Halifax.

- **Lack of Canadian operational data**

A lack of data on the impacts of temperature variation on battery performance, as well as the durability of electric components in snow and salt conditions are perceived as barriers to implementation. Transit providers emphasized that the selection process of powertrain technology is mainly informed by practical operational data in similar contexts, not by laboratory tests. Transit providers clearly stated that they demand real-world operational data under a variety of network conditions, not proof-of-concept trials that are based on relaxed operational conditions.

“We look at a lot ... we talk to a lot of other companies and see what’s working for them. We really can’t afford to make a mistake when we make a purchase. So we really have to do our research beforehand” – Kings Transit, Kentville.

- **Health and safety concerns**

Health, and safety regulations of electric bus are regarded as part of the unknown. Transit providers highlighted the lack of knowledge/regulations/policies related to safe operation/maintenance of the electric bus in their current operational manuals.

“And again the health and safety aspect dealing with a higher voltage is a little concerning too” – HSR, Hamilton.

4.2 Financial and operational feasibility of Electric bus

The operational feasibility of the electric bus has emerged as the key factor that governs the adoption of electric technology in the transit context. Six distinct aspects are identified that contribute to operational feasibility.

- **Operational availability**

The data highlighted that the diesel bus is always used as a reference in operation, with a range of 500-700 km and refueling time of 1-3 minutes. Adding to that are demands for 20 to 22 hours of operation in bigger metropolitan areas. Electric buses are seen to be not capable of providing similar performance.

“We got a new bus that goes out for 22 hours or so a day. And our range, our range for one of those buses is 400 miles. Just before we get into those electric buses we talked about, we’re not even close” – TTC, Toronto.

- **Network optimization**

Given current technological capabilities, transit providers argued that only specific routes could fit the prevailing range/charging-time profile of the electric bus. There was thus a perception that electric buses would constrain flexibility of use across routes.

“They will be limited I think... I don’t think it will be usable for every service, there’ll be very specific ones... it will take a lot of work to work through the steps of how you select your routes I think” – Calgary Transit, Calgary.

- **Human resources**

Availability of human resources is identified as an integral component for the implementation of the electric bus. Transit providers argued that electric technology requires different skill sets, especially from mechanics. The availability of trained mechanics represents a current problem for transit providers in Canada. Hence recruiting new mechanics with the required skill sets is a challenging task.

“To take on electric knowledge ... it would be a lot to upgrade your mechanics. Mechanics are really a rare commodity right now right across the country” – Kings Transit, Kentville.

- **Total cost of ownership**

Cost is the main driver for the decision-making process in the transit context. Transit providers argued that current theoretical LCC models do not fully consider all cost aspects associated with transit operation. They claimed that current LCC models do not provide “apples to apples” comparisons owing to the varied operational features between different technologies at the network level.

“It’s that clock I was telling you about and then the whole thing... if it’s (implementing electric bus) going to mean a re-tooling of your maintenance regime, of your lifecycle regime, of your ‘where can you use the buses. It’s very difficult. It is no longer bus-to-bus comparison, the entire service should be considered” – OC Transpo, Ottawa.

- **Standardizations of electric technology**

Developing common standards is identified as a critical component for the feasibility of the electric bus. Providers have expressed their unwillingness to be married to a single vendor due to the technological variation in electric bus components (battery, charger, and voltage).

“We have to go for tenders ... it’s not going to be cost efficient and workable to have different batteries, voltages, chargers, and such from bus build to bus build, so the industry does have to come up with standards” – Winnipeg transit, Winnipeg.

4.3 Decision making & fleet management

The decision making process for transit operation has a profound impact on the implementation of the electric bus. Although it involves various aspects, four significant components emerged from the interviews.

- **Organizational policies & decision making**

The data highlighted the lack of any green/electric policies that guide the implementation of electric bus technology at the transit provider level. In general, the transit decision-making process is governed by three main components: reliability of service, risk mitigation, and cost-revenue analysis. The evidence suggests that the electrification of bus transit is not actively considered in the current decision making process.

“We’re very risk-adverse ... when you’re dealing with a large volume of public funds, the last thing anybody wants to do is have your picture on the front of the newspaper with this article about the disaster of electric buses, it’s really got to be a proven technology and a cost-effective technology I think” – Metro Transit, Halifax

- **Fleet management strategy**

Apart from the decision-making process, fleet management strategies are identified as major roadblocks for the implementation of the electric bus. Fleet management is governed by achieving maximum integration in operation, and accordingly operational requirements are essential for selecting powertrain technology. The data highlighted that, in practice, fleet management is divided into two phases: fleet renewal and fleet expansion. With respect to fleet renewal, providers currently focus on the replacement of old high-floor diesel buses with new “clean” diesel buses and CNG in some cases. This focus is motivated by GHG reductions and the achievement of full operational integration.

“We purchase new vehicles to replace old vehicles. So, at that point we are replacing vehicles that were built in the early 80s, so we felt that environmentally it made more sense to replace more of those old vehicles with new clean diesel than replacing a smaller number with a hybrid that was only marginally more fuel efficient” – Winnipeg transit, Winnipeg.

- **The U.S. influence**

There is a strong belief across the sector in Canada that the U.S. market is guiding technology choice and R&D direction for the electric bus. Transit providers emphasized that Canada follows the U.S. market and it has little, if no, influence on the industry. In this respect, they argued that manufacturers' priorities do not necessarily meet transit demands in Canada, which hinders the implementation of the electric bus.

5. Developing a business case

Several avenues for interventions were advocated through the discussion to accelerate the implementation of the electric bus in the transit context. A dominant common theme of the proposed interventions is the development of a practical business case that alleviates the current problems associated with electric bus operation. Interview participants have identified several stakeholders to play major roles in building a successful business case for electric bus operation including policy-makers, manufactures, industrial experts and transit providers.

Overall, the decision-making process for implementing the electric bus in transit could be argued as risk, operational, and cost centric. These three factors are jointly, and/or separately, linked to all the themes/categories that emerged from the data as illustrated in Table 3. Together, these factors guide the decision-making process. Miles and Potter [4] have highlighted that risk transfer is essential for transit providers to implement electric buses in transit. Therefore, a feasible business case MUST address these three factors.

Table 3. A business case for the implementation of the electric bus

	Attitude towards E-bus	Operational Feasibility	Decision making process	Developing a business case
Risk	High risk associated with being an early adopter, coupled with the fear of obsolescence	Risk of influencing service reliability, and reducing ridership rates	Risk-free decision making when dealing with public funds, and taxpayer money	Risk mitigation through establishing Canadian operational data
Operation	Technology is viable but still in development phases, with a lacked of defined future technological development	Expected increase in fleet size, with limitation in Range/charge-time, and operational flexibility	Operation is optimized with long range & economic diesel and CNG buses	Demands for demonstration projects that highlight operational feasibility in Canada
Cost	Perception of high cost associated with the electric bus	Total cost of ownership is high, and high hydro rates	Not having financial/capital capability for implementation	Federal support and monetary incentives are essential

Transit providers advocated that a business case should be implemented in a top-down approach. They emphasized that individual initiatives are not expected to generate enough impacts on the market, hence a national level approach is regarded more comprehensive. In addition, the development of a successful business should pay much attention on the selection for business case context. In this respect, some providers argued that small-medium cities are a good environment for implementing the electric bus as it features less demanding operational conditions.

“Well typically I think it would come top-down... doing those things in isolation don't really help, you know? Like a trial in Calgary is good, it will tell people in Calgary what's good, but it doesn't help people necessarily in B.C. The operating environment is so different... So there needs to be something on a more... on a higher level I think actually” – Calgary Transit, Calgary.

6. Conclusions

This study investigated the key factors that hinder the implementation of electric bus technology in the Canadian transit context. In particular, a grounded theory based qualitative analysis was carried out to better understand the perspectives of service providers towards the implementation process. This perspective is an under-researched one. The findings highlighted aspects of required interventions that inform different sets of demands if jurisdictions are to implement electric buses in transit.

The findings highlight that, at the present time, there is little desire from service providers to implement electric bus technology in a daily full-network operation. This is attributed to the sensitivity of electrical bus operation in various respects. The current risk-averse decision-making environment is also highlighted as a reason for not seeing the electric bus as an economical, and operational capable powertrain technology. Standardization, technology anxiety, and full network operational feasibility were also identified as roadblocks for the electrification of bus transit. The findings indicated as well that the implementation of electric bus hinges on political support. Transit providers expressed a clear desire for political support that transfers the financial risk associated with higher capital costs. Targeted political efforts directed at selected transit agencies are advocated to be essential.

Finally, it is necessary to acknowledge that electric bus technology will continue to be sensitive to operational variation. This implies that, at the present time, tailored technological configurations are essential to meet the operational demands of transit service at a network level. Future investigation, however, should be directed at eliminating this sensitivity through technological advancement and optimization models that fully consider the daily operational constraints.

Acknowledgment

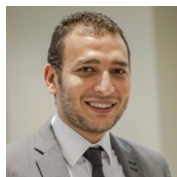
The authors of this article would like to acknowledge support from Social Sciences and Humanities Research Council of Canada (SSHRC) Grant No: 886-2013-0001.

References

- [1] Kamruzzaman M, Hine J, Yigitcanlar T. Investigating the link between carbon dioxide emissions and transport-related social exclusion in rural Northern Ireland. *International Journal of Environmental Science and Technology*. 2015.
- [2] Pihlatie M, Kukkonen S, Halmeaho T, Karvonen V, Nylund N-O. Fully electric city buses - The viable option. *IEEE International Electric Vehicle Conference (IEVC)*. Florence, Italy 2014.
- [3] Offer GJ. Automated vehicles and electrification of transport. *Energ Environ Sci*. 2015;8:26-30.
- [4] Miles J, Potter S. Developing a viable electric bus service: The Milton Keynes demonstration project. *Research in Transportation Economics*. 2014;48:357-63.
- [5] Kennedy C. Key threshold for electricity emissions. *Nature Climate Change*. 2015;5:179-81.
- [6] Poullikkas A. Sustainable options for electric vehicle technologies. *Renew Sust Energ Rev*. 2015;41:1277-87.
- [7] Lajunen A. Energy consumption and cost-benefit analysis of hybrid and electric city buses. *Transport Res C-Emer*. 2014;38:1-15.
- [8] Wang R, Wu Y, Ke W, Zhang S, Zhou B, Hao J. Can propulsion and fuel diversity for the bus fleet achieve the win-win strategy of energy conservation and environmental protection? *Applied Energy*. 2015;147:92-103.
- [9] Bayindir KC, Gozukucuk MA, Teke A. A comprehensive overview of hybrid electric vehicle: Powertrain configurations, powertrain control techniques and electronic control units. *Energ Convers Manage*. 2011;52:1305-13.

- [10] Chan CC. The state of the art of electric, hybrid, and fuel cell vehicles. *P Ieee*. 2007;95:704-18.
- [11] Kühne R. Electric buses – An energy efficient urban transportation means. *Energy*. 2010;35:4510-3.
- [12] Lu LG, Han XB, Li JQ, Hua JF, Ouyang MG. A review on the key issues for lithium-ion battery management in electric vehicles. *J Power Sources*. 2013;226:272-88.
- [13] Khaligh A, Li ZH. Battery, Ultracapacitor, Fuel Cell, and Hybrid Energy Storage Systems for Electric, Hybrid Electric, Fuel Cell, and Plug-In Hybrid Electric Vehicles: State of the Art. *Ieee T Veh Technol*. 2010;59:2806-14.
- [14] Ribau JP, Silva CM, Sousa JMC. Efficiency, cost and life cycle CO₂ optimization of fuel cell hybrid and plug-in hybrid urban buses. *Applied Energy*. 2014;129:320-35.
- [15] Nylund N-O, Koponen K. Fuel and Technology Alternatives for Buses - Overall Energy Efficiency and Emission Performance. Finland: VTT Technical Research Centre of Finland; 2012.
- [16] García Sánchez JA, López Martínez JM, Lumbreras Martín J, Flores Holgado MN, Aguilar Morales H. Impact of Spanish electricity mix, over the period 2008–2030, on the Life Cycle energy consumption and GHG emissions of Electric, Hybrid Diesel-Electric, Fuel Cell Hybrid and Diesel Bus of the Madrid Transportation System. *Energy Convers Manage*. 2013;74:332-43.
- [17] Ou X, Zhang X, Chang S. Alternative fuel buses currently in use in China: Life-cycle fossil energy use, GHG emissions and policy recommendations. *Energy Policy*. 2010;38:406-18.
- [18] Frost & Sullivan. Strategic Analysis of Global Hybrid and Electric Heavy-Duty Transit Bus Market (NC7C-01). Frost & Sullivan Publication; 2013.
- [19] Filippo GD, Marano V, Sioshansi R. Simulation of an electric transportation system at The Ohio State University. *Applied Energy*. 2014;113:1686-91.
- [20] FCH-JU. Urban buses: alternative powertrains for Europe. Europe: The Fuel Cells and Hydrogen Joint Undertaking (FCH JU); 2012.
- [21] Xu YZ, Gbologah FE, Lee DY, Liu HB, Rodgers MO, Guensler RL. Assessment of alternative fuel and powertrain transit bus options using real-world operations data: Life-cycle fuel and emissions modeling. *Applied Energy*. 2015;154:143-59.
- [22] Hatzopoulou M, Miller EJ. Institutional integration for sustainable transportation policy in Canada. *Transport Policy*. 2008;15:149-62.
- [23] Li J-Q. Battery-Electric Transit Bus Developments and Operations: A Review. *International Journal of Sustainable Transportation*. 2014:1-22.
- [24] CUTA. Canadian Transit Fact Book. CUTA Data. Toronto, CA: Canadian Urban Transit Association (CUTA); 2014.
- [25] Glaser BG, Strauss AL. *The Discovery of Grounded Theory: Strategies for Qualitative Research*: Aldine de Gruyter; 1967.

Authors



Moataz Mahmoud is a Postdoctoral Research Fellow at McMaster Institute for Transportation and Logistics. He is also a tenure Assistant Professor at Faculty of Engineering, Assiut University. He holds a MSc degree in Urban Planning from University of Rome, and a PhD in Transportation Planning from University of Ulster, UK. His research focuses on the utilization of perception and attitude measures in transportation research and includes public transit quality, electrification of transit, consumer adoption of EVs, sustainable mobility, and transit oriented development.



Mark Ferguson is Senior Research Associate with the McMaster Institute for Transportation and Logistics. He holds a Ph.D. in Geography from McMaster University. His academic knowledge is complemented by over a decade of private sector experience in location consulting. Areas of interest and expertise include: electric mobility, sustainable transportation, goods movement and logistics, statistical modelling, spatial analysis and urban and economic geography.



Pavlos Kanaroglou is a Professor Emeritus in the School of Geography and Earth Sciences at McMaster University and Director of the McMaster Institute for Transportation and Logistics. From 2002 until 2015 he held a Tier 1 Canada Research Chair in Spatial Analysis. Areas of research focus include: urban and transportation modelling and issues, spatial analysis, econometric modelling, complex adaptive systems and sustainable transportation.