Research Statement - Abhilash C. Singh

Information and communication technologies have enabled vast data collection at the consumer level. These novel data streams coupled with statistical, econometric and machine learning (ML) methods enable a deeper understanding of consumer decision-making. This is very useful in domains like transport, healthcare, public policy, e-commerce and marketing. However, for reliable consumer behaviour modelling, we need accurate predictions along with uncertainty quantification for actionable quantities, for example, confidence intervals for consumer-level effects of a public transport intervention in an ex-ante policy analysis. My research builds **solutions for behavioural modelling** that address the statistical and computational challenges associated with estimating and predicting decisions. My research spans across *applied econometrics, machine learning and choice-based optimization.* On one hand, my background in transportation engineering is critical in **understanding the behavioural aspect of decision-making**. On the other hand, my training in statistics and econometrics helps me **design efficient models** for the problem at hand, reason about the data needed and **model stochasticity** in these models. My approach to research is **centralized yet diverse**, with a focus on **econometric and statistical models** serving as the foundation for all other aspects, **in collaboration with domain experts** from institutions such as the University of Texas, University of Toronto, Imperial College London, University of Tokyo, and Technical University of Munich. In the years to come, I plan to harness this research capital and make significant contributions to scientific research. I now provide an overview of the challenges and contributions of my research in Behavioural modelling and Urban systems.

Behavioural Modelling

Consideration-set formation: Complex cognitive decisions often involve a large number of alternatives. Identification issues arise as the decision-makers *sample* or *consider* the alternatives endogenously. Almost all discrete choice models used in practice and research are based on compensatory decision processes, with utility-maximization being the most common example. *My research [1] proposes a non-compensatory decision tree method to accommodate behavioural realism in the formation of consideration sets.* The decision trees resolve the ambiguity in deriving exact conditions for each observation by using disjunction-of-conjunctions decision rules, which ensures that no observation is ever described by more than one conjunctive condition. These consideration probabilities across all alternatives are then utilized to form consideration sets, conditional on which a choice model is estimated. The results of this analysis provide insight into factors that lead to the consideration or rejection of alternatives in a decision-process based on socioeconomic and demographic differences, such as income level, vehicle ownership, and household structure. This research provides a deeper understanding into residential segregation and provides policymakers with information to promote equitable neighbourhoods.

Endogeneity: Endogeneity can be observed in several types of discrete choice models used in land use and transport analysis, leading to inconsistent parameter estimates. *My research [2] addresses simultaneity endogeneity between residential location choice and travel behaviour by devising a multivariate model system.* The proposed framework simultaneously estimates both variables to provide a clearer identification of the "true" effect of the built environment on household trips without problems of multi-collinearity with other built environment characteristics. This analysis highlights the residential neighbourhood dissonance of transit riders, such that locations with higher transit accessibility are not necessarily where people who make more transit trips reside. *In another research [4] we aim to develop a multivariate modelling framework to capture the dependencies between the choice set formation, discrete choice, and endogenous variable models through the error structure of a multivariate normal distribution.* By accommodating instrumental variables in the endogenous variable model, this framework simultaneously corrects the endogeneity bias on the estimates of the corresponding parameters in the discrete choice and its choice set formation models. Our proposed efficient Markov Chain Monte Carlo algorithm consists of the Gibbs sampler and MH algorithms at different estimation steps.

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Choice-based optimization: *In another ongoing choice-based optimization analysis [3], we propose a dynamic pricing approach for electricity consumption by electric vehicles during overnight charging* that balances the objectives of minimizing the overall electricity cost for the households and ensuring that the total electricity demand does not exceed the network capacity. This research proposes a new optimization model with dynamic pricing, and contributes to the development of more efficient and sustainable energy systems by reducing peak electricity demand and increasing the integration of renewable energy sources.

Future directions: Extending my work on employing decision trees for non-compensatory behavioural modelling, I would like to develop models accounting for local and global heterogeneity, estimation uncertainty and context-dependent preference heterogeneity. Further along, these model-based recursive partitioning algorithms can help advance the fields of decision science and statistics. The challenges pertaining to this goal are encapsulating micro-econometric identification and inferential interpretation of ML models. Extending my work on endogeneity, my goal is to propose and validate adequate instruments that can be obtained from observed data to deal with omitted variable and measurement endogeneity in travel behaviour models. The challenges pertaining to this goal are firstly, to understand the implications of violations of assumptions in Control Function approach in discrete choice models, and secondly, to quantify exogeneity-relevance trade-off to get bounds on the relevance condition requirement under different levels of endogeneity problem and exogeneity assumption violation. Extending my work in choice-based optimization, the challenge lies in the non-linearity of the resulting optimization problems, making them difficult to solve in a tractable way. My goal is to develop an efficient method that is general to deal with different types of choice models and realistic business constraints. En route I envision many opportunities to build new scientific collaborations in economics, operations research and transportation.

Urban Systems

Transport Systems: Vehicular emission is among the top causes of global warming, thus calling for an understanding of factors which may help reduce vehicle miles travelled (VMT). *My research proposes a generalizable framework [5] that estimates relative contribution towards VMT's explained variance proportioned by socioeconomic and demographic characteristics, residential built environment attributes, self-selection effects, and social-spatial dependency effects.* The research shows that household socioeconomic and demographic characteristics have a greater impact on VMT than the built environment and self-selection. Contemporary interest in adoption of autonomous vehicles (AVs) and their promise to support climate outcomes calls for a deeper understanding on promoting their adoption. *Therefore, we developed a model [6] to measure an individual's willingness to adopt an Autonomous Vehicle (AV) based on factors such as lifestyle, opinion on productive use of time, safety perception, automation levels, and socioeconomic variables.* The framework utilizes an endogenous latent-class segmentation methodology to account for group taste heterogeneity indicating that consumers who are willing to pay more for the technology do so due to increased productivity and safety during commuting. Another paper *[7] used psychological theories to capture individual attitudes towards AV acceptance*, opening up the possibility of developing psychometric behaviour choice models.

Future directions: My future research *(extension of prior efforts [8, 9])* aims to develop a multivariate modelling formulation that separately measures residential self-selection effects and true built environment effects, considering the presence of multi-collinearity between the residential location choice descriptor(s) and built environment attributes. I will also develop a methodology that unravels true effects from self-selection effects when explanatory variables are correlated with the endogenous descriptor used in VMT equation modelling. I will further explore social-spatial dependency effects in joint models of discrete-continuous variables. Building on the work to understand technology adoption, I aim to develop *socio-psychological econometric models* based on the Theory of Reasoned Action and *socio-domestic acceptance models* based on the Technology Acceptability Model, particularly for the use-case of Artificial Intelligence and its adoption in day-to-day life.

References

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