Computing Science

TODO TITLE

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TODO FINALISE Honours Project

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Abstract goes here

1 Introduction

2 Literature survey

intro to literature review

2.1 Taxis

Taxis (also known as *taxicabs*) are an important part of public transportation. Because of their prevalence worldwide and importance in transportation a wide range of literature has been produced on taxis. For this project, the most relevant area of this literature is economical modelling of taxi markets, an overview of which is given by Salanova et al. (2011). A major topic in the research and discussion on taxis is taxi market regulation, and parts of it are relevant and will be considered in some detail. Three different types of taxi markets can be distinguished: cruising taxi market when a passenger hails the taxi no the street, phone-order taxi market, and taxi ranks where multiple taxis wait for passengers.

Regulation

Regulation is a controversial topic for taxi research as no consensus has been reached on whether it is recommended. Cairns and Liston-Heyes (1996) investigated economic workings of taxi markets and incorporated results of earlier research in their economic equilibria findings. They concluded that regulation is needed to achieve non- negative profits (the so-called economic second best). OECD (2007), cited by Salanova et al. (2011) listed arguments both for and against regulation as observed in different countries, and noted that markets with widely varying regulation can operate successfully. It is important to note that some markets considered *deregulated* still have some form of fare regulation, for example, taxis in New Zealand are required to list their maximum fares based on time and distance, but are not forced to follow them (Gaunt 1995).

Economic modelling

Taxi market modelling was first done by Douglas (1972), according to Salanova et al. (2011). He investigated a regulated cruising-taxi market (where a customer hails a taxi on the street on visual contact) and defined the fundamental taxi problem to be finding an equilibrum of an optimal level of service matching an optimal price. His limited model has been used as reference by all the later authors cited by Salanova et al. (2011) that have extended it to other taxi markets and factored in more environmental influences. De Vany (1975) researched regulated taxi markets organised as a franchised monopoly, using a medallion system, and having free entry. With the goal of finding equilibrium output, capacity and utilisation he suggested a formula tor passenger demand depending on taxi fare, passenger value of time and waiting time. Manski and Wright (1967) analysed the taxi market from a purely economical point of view and conclude that in addition to exogenous variables, passenger demand for taxi services is also directly related to taxi supply through waiting time. Similarly, taxi supply is influenced by taxi utilisation, which in turn directly depends on passenger demand.

The most recent publications in this area are sophisticated models based on the network model for cruising-taxi market by Yang and S. Wong (1998). This network was modelled as a graph and assumed constant taxi demand and supply, passenger demand was represented as origin-destination matrices.

Finally, this paper suggested an algorithm to find an equilibrum for the optimal number of taxis in a market and equations to calculate taxi utilisation and customer waiting time. In contrast, Yang, Lau, et al. (2000) focused on supply and demand to recommend optimal policies for taxi regulation in Hong Kong and based their model on various data sources. A number of exogenous and endogenous variables affecting taxi market were identified, and equations were suggested to calculate them: passenger waiting time, percentage of occupied taxis, vacant taxi headway, daily taxi passenger trips and taxi waiting time. This model can be used to forecast taxi demand, taxi utilization and service quality, although the authors warned that it does not take in account all of the complex supply- demand relationships in taxi market.

Consequently Yang, S. C. Wong, and K. Wong (2002) continued to evaluate the supply-demand equilibria of taxi market started by Yang and S. Wong (1998) and Yang, Lau, et al. (2000), resulting in the conclusion that the spatial characteristics of a network where taxis are operating strongly influence supply and demand, and should bear weight when evaluating regulatory policies.This study focused on social surplus (the sum of customer surplus and producer surplus) as the key objective of taxi markets. Four different regulatory frameworks that could be applied to taxi markets were investigated: free entry and unconstrained fare, free entry and regulated fare, regulated entry and unconstrained fare, and regulated entry and regulated fare. All of these cases were investigated with both competitive and monopilistic markets, and equilibria were found.

K. Wong et al. (2008) extended this model to heterogenous vehicle and user classes, and included congestion which is a major issue in reality but was ignored by earlier research. Yang, Fung, et al. (2010) proposed a nonlinear fare structure to correct market and regulatory inefficiencies, and applied it to a similar model. The way how cruising taxis and customers find each other was researched by Yang, Leung, et al. (2010), paying particular attention to customer behaviour: this study permitted customers to use other modes of transport e.g. public transit or walking to find taxis and/or reach their destinations.

Demand and supply

Taxi demand is a part of the total demand for transportation. There are two approaches to modelling demand for public transportation: aggregate and disaggregate. Aggregate models are macroeconomic, while disaggregate models are microeconomic and based on the individual agents in a system. Recently disaggregate models have emerged as the main method of modelling demand, but these models require detailed microeconomic data for a system. Because of difficult processing of the large datasets, applying disaggregate models usually involves some form of aggregation. Customers' value of time (VOT) and value of reliability (VOR) are the most important quantities determining the demand for public transportation. Both VOT and VOR derive on customers' characteristics and environment they are in, for example, their income, whether the planned trip is for pleasure or a commute to work, and even the tax rates. Aggregate models using VOT and VOR have been developed as well, although VOR has been researched significantly less. (Small and Verhoef 2007)

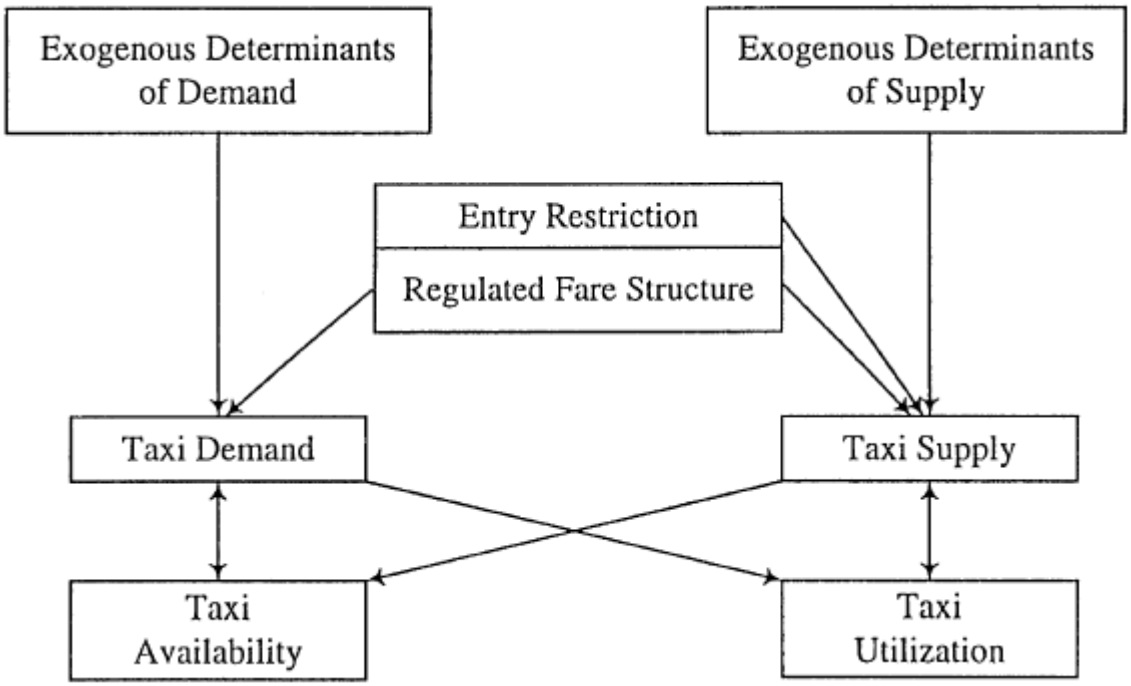

Figure 1: The demand-availibility-utilization-supply relation in a taxi market. **NEED PERMISSION**

Yang, S. C. Wong, and K. Wong (2002) cites Manski and Wright (1967) on the complex structure of demand in taxi markets, shown in Figure 1. Both taxi demand and supply are infulenced by exogenous variables (and regualtion policies, if any). Taxi demand influences taxi availability and vice versa. Similarly, taxi supply influences taxi utilization and vice versa. Taxi demand influences taxi utilization and thus indirectly influences supply, similarly taxi supply influences taxi availability and thus indirectly influences demand.

Customer demand is modelled as a function of waiting time and fare price in many studies: Douglas (1972), De Vany (1975), Cairns and Liston-Heyes (1996), and Yang, S. C. Wong, and K. Wong (2002) use customer waiting time as a proxy for service quality. According to Salanova et al. (2011), Manski and Wright (1967) used a Poisson process (a probabilistic stohastic function) to simulate demand. Yang, S. C. Wong, and K. Wong (2002) use a disaggregate demand model (separately for each origin-destination pair), where waiting time depends on the number of vacant taxis in an area near the customer and price depends on the distance covered; Yang, Fung, et al. (2010) added travel time as an additional variable indicating service quality and assumed that demand decreases as waiting time increases. Yang, Leung, et al. (2010) took a slightly different approach by modelling customer demand as their willingness to pay to reach a destination, based on their subjective monetary value for using different modes of transport for reaching a destination; therefore the demand for taxis in this study was only a part of the total demand for transportation.

2.2 Reinforcement learning

3 Software and simulation design

3.1 Design

The approach suggested by this project is not compatible with a market where fares are regulated, at least in the current form of regulation that specifies a formula to calculate fares based on some variables, usually time and distance. Other ways of regulation, for example, entry conditions, are compatible with the suggested approach and do not require any further investigation.

Phone-order market vs cruising taxi market (vs taxi rank market?)

4 Implementation and results

5 Evaluation and discussion

6 Conclusion

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