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Travel Demand Management in an Auto Dominated City: Can Travel Behaviour Be Nudged in the Kingdom of Saudi Arabia?

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Abstract: Car ownership and use in the Kingdom of Saudi Arabia (KSA) are very high due to the high income, the low fuel prices and the near absence of public transportation in the Kingdom. Currently, the Kingdom is going through a massive transformation and entering a new era of national reforms. One of the main aims of the national reforms is to reduce car dependency and enhance more sustainable options of travel such as public transportation in the KSA. In order to achieve such an aim, there are two hurdles: Firstly, there must be a provision of decent public transportation options, and secondly, there is a need to influence travel behaviour and encourage the shift from private cars to public transportation. For example, in Riyadh city, an impressive metro system is being constructed and will start operation in 2023. To influence travel behaviour, travel demand management measures (TDM), in particular pricing measures, can be adopted and implemented, in order to help and support achieving the target. The main aim of this paper, therefore, is to assess the attitudes of Saudi nationals towards—and willingness to accept—pricing measures and their possible impacts on their travel behaviour in the city of Riyadh. The methodology includes collecting data using an online survey on travel behaviour and attitudes in Riyadh and calibrating multinomial logit modal choice models. The participants in the survey were asked to report their support of the pricing measures for the objective of reducing congestion in the city, improving road safety or reducing travel time. The results show the highest support towards pricing measures for improving road safety, reducing travel times and, lastly, reducing congestion in the city.

Keywords: KSA; Riyadh; traffic congestion; pricing measures; travel demand management

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1. Introduction

Many world cities are facing major problems related to the increase in car ownership and use, increasing congestion and the measurement and assessment of these traffic indicators [1]. These increases present serious risks and travel delays, environmental pollution and lessened traffic safety [2,3]. Transport is a major contributor to the global CO_2 emissions, global warming and negative environmental impacts. Measures and programs that can reduce these negative impacts are urgently needed in all countries that aim to achieve sustainability.

Over the past few decades, many studies have investigated the factors that affect modal choice and assess possible travel demand management (TDM) measures and programs that can be exploited to achieve a modal shift towards public transportation [4,5]. Most studies addressed the impact of personal and household attributes, as well as the attributes of the transport system in mode choice [6,7]. The primary theoretical approach of most of this research is in line with the consumer choice theory, that is, rational decision-making and full information [8].

Travel demand management (TDM) is a concept that has been in use for few decades. It refers to one measure or a package of measures that aim at altering travel behaviour

choices and decisions and reducing negative impacts of the transportation systems. Numerous measures and programs for traffic demand management (TDM) have been proposed and implemented in many world cities in order to reduce these negative externalities [9,10]. These include pricing policies, public transportation, alternative clean travel options, parking pricing and management, raising awareness and educational measures and others. There are very few, if any, studies on TDM measures, however, that have been carried out in most of the Kingdom of Saudi Arabia (KSA)'s cities. In the KSA, the main traffic management approach that has been adopted has been to "predict and provide" rather than "predict and manage". Therefore, TDM was not previously exercised in the Kingdom. Consequently, most urban travel in the country has been carried out using the private car, which became the most dominant mode of travel. In addition, there were many cultural factors that governed Saudi families' travel patterns and in particular women's travel behaviour over the past decades [11,12]. As a result, the private car travel has never been seriously discouraged in the country.

With the new vision 2030, there are genuine efforts and opportunities to attempt to adjust these patterns of high car ownership and use and encourage the population to shift towards more sustainable options of travel in most cities of the Kingdom. Riyadh is the capital of KSA and the most populated city, with a total reported population of 7.6 million citizens in 2020 [11]. The city of Riyadh is located at the eastern section of the Najd hill [12,13]. The Saudi nationals represent over 65% of the population while expatriates represent just under 35%. The population density is about 2379 inhabitants per square kilometre; the female population accounts for just over 43%, while about 55% are males [13]. The Public Transport authorities in Riyadh aim to operate a public transportation system that started in 1979 and are aiming to provide high levels of public transportation locally and regionally. However, the current level of service and level of usage of the Saudi public transportation system are very limited. Statistics show that over 85% of the daily trips in Riyadh (over eight million) are carried out by private cars (solo driving) and 2% of the trips are carried out by buses [12,13]. Between 1996 and 2018, private vehicle ownership increased by over 200% [11]. Until lately, the immense majority of Riyadh's population have never experienced public transportation modes of travel and they rely entirely on driving their private cars during most of their travel. However, these trends seem to be about to change.

With the Kingdom of Saudi Arabia (KSA) going through national transformations and entering a new era, sustainability has become one of the main features of that era. There are many new projects that are aiming at promoting renewable energy objectives, clean energy purposes and encouraging sustainable options of travel. Car dependency and alternative fuels are at the heart of those projects. For example, the newly built Riyadh metro system is planned to be the backbone of the city's public transportation system. It is currently near starting operation with plans for opening in 2023. The Riyadh metro system will be operating six lines with a total length of 178 km and 85 metro stations that are integrated with the bus network 1200 km in length. Riyadh Metro is planned to be an improvement in the existing infrastructure for public transportation, advancing accessibility to public transportation and improving transit-oriented developments. It is very vital, therefore, not only to select the appropriate TDM measures to be implemented along with the metro, but also to assess the potential impacts and acceptability of such policies. In this research, the impacts of pricing measures are investigated to assess their possible impacts on reducing car usage and enhancing public transport patronage. This is very important, since most of the population in the KSA has been relying heavily on private modes of travel for many decades due to many factors including cultural considerations. Hence, while improving public transportation opportunities is a very good incentive, by itself it cannot achieve the modal shift. In order to reverse this behaviour, the cities need to implement both incentives, such as improving public transportation provision and disincentives such as pricing measures.

This paper investigates the level of acceptability of a hypothetical road pricing measure that could be implemented in the city to reduce demand on the use of the private cars and increase the use of public transportation. The paper also assesses the factors that affect the choice of mode of travel in the city of Riyadh, the capital city of KSA, in the current era. The paper is structured as follows. Section 2 is an overview of relevant previous studies on TDM measures, modal choice models, and travel attitudes towards available modes of travel. The methodology is presented and discussed in Section 3. General analysis of the data is presented in Section 4. Attitudes towards TDM measures are analysed and discussed in Section 5. Modal choice statistics and modelling are presented in Section 6. The main findings of the research are concluded in Section 7, and limitations are presented in Section 8.

2. Literature Review

Most of the existing transportation systems in the world suffer from congestion, delays, air pollution and worsening safety levels. A lot of these problems happen as a consequence of high car ownership and use and the decline of the public transportation systems. Therefore, most world cities and local authorities are seriously occupied to fully understand the level of traffic problems and come up with appropriate measures and measures that can mitigate the negative environmental impacts of traffic, which may also lead to improved road safety [14–17]. Many transport measures have been assessed and tested theoretically and empirically for the purpose of managing congestion and the demand for travel in cities. These measures include pricing, parking management, public transportation, access control, traffic signals, and raising awareness and educational policies. Some of these measures can be designed mainly to reduce congestion while others are designed to reduce negative environmental impacts or improve road safety [18].

In order to achieve these goals, travel behaviour and choices have to be understood and managed, including choices of modes, times, routes and destinations, which all affect the level of congestion of the roads [19–21]. Each of these choices is associated with parameters including the quantitative (vehicle travel times, travel costs, etc.) and the qualitative variables (comfort and convenience). It is challenging, however, sometimes to achieve a modal shift and influence travel behaviour based on modifying travel times and travel costs, in particular in situations where there is high car dependency and low or no restrictions on car use [20]; cultural and habitual factors also influence travel decisions. While pricing measures have proved to be effective mostly in the West [22–25], their influence on travel behaviour in other geographical places is not yet fully investigated [26,27]. Further research in this area is needed.

The influencing factors on travel behaviour include gender. Gender is a significant factor that influences travel behaviour, attitudes and choices of modes of travel. Some research and publications have indicated that women and men's travel behaviour are significantly different. Some studies reported that women are more likely to use sustainable travel behaviours and modes of travel than men. Women in Sweden were reported to be more positive towards sustainability and more likely to cut down their car usage than men [28]. In addition, it is found that women's commuting distances tend to be shorter but more complicated than those of men [29–31]. Similarly, a German study [32] found that gender impacts affect travel behaviour. Generally speaking, there has been significant research on gender differences and travel patterns in the developed countries, with less research having been done in the developing countries [12,13]. An important factor for the Eastern countries is the culture. It appears that the cultural factors do have more significant impacts on travel behaviour in the Middle Eastern countries, for example [31,33–36]. Some studies have attempted to examine gender and cultural differences in travel behaviour in the Arab world [37–39]. In such countries, women's travel attitudes and behaviour are affected by economic and geographical and cultural factors as well as other social and cultural differences and restrictions. More research is certainly needed in these areas.

Age and marital status are another two significant factors that influence travel behaviour. Two studies [28,29] concluded that young men travelled substantially less than their counterpart young men in previous generations, which could indicate that different generations face different socio-economic contexts which impact on mobility trends. Employment opportunities represent a main core of the investigations in the area of gender research [29,30]. Geographical mobility was also considered in the Egyptian labour market in the period of 1988–1998 [37]. The researchers concluded that unlike young females, single young males have had to significantly increase their geographical mobility to access regular paid work in the private sector. This has led to an increased gender gap in geographical mobility rates over the decade of the 1990s.

A study on the demographic variables in Libya, such as age and gender, has shown a significant contribution towards explaining mode choice behaviour [38]. The study showed that while men represented a higher percentage of public transportation users, of those who currently use cars men showed less willingness to shift to public transportation than women, while women who use cars were more willing to shift to buses should the level of service improve. This might be due to cultural and habitual factors, as shown in another study in Oman [39]. Other researchers have observed gender differences in students' travel behaviour in the Arab countries. A study that investigated travel characteristics of female college students in Saudi Arabia reported that gender is one of the main factors affecting mode choice for students [40]. Compared to females, males were more likely to use the bus; while 57% of men travelled as car (or van) passengers and 39% travelled by bus, all females travelled by private cars with a driver or as car passengers, and over half (53%) of them were captives of their current mode of transport. It should be noted here that women were not allowed to drive during the reported study.

Attitudes towards travel behaviour may additionally be influenced by several other factors including education, number of members in the household, car ownership and use, income, accessibility, and household size, amongst many other factors. The authors of [17] investigated the role of social influence on green travel behaviour in China. Travel behaviour and attitudes toward non-working trips were modelled, taking into account household structure and lifestyle and the built environment [24]. Sustainable travel decision-making was examined, taking into consideration household structures [41]. Attitudinal theories were utilized to study attitudes towards car ownership and use [42]. A qualitative study to assess attitudes towards private cars and public transportation was carried out, assessed and modelled in many studies [43,44]. Travel behaviour and the influence of residential relocation and vehicle ownership was explored in [45]. Impacts of socio-economic factors on choices of more sustainable modes of travel were investigated in a case study in India [46]. Travel behaviour and choices of travel modes in Saudi Arabian case studies were investigated and the role of social factors was assessed [47,48]. Mobility patterns and their impacts on culture and the structure of the household and gender differences were investigated in [49]. Impacts of lifestyle on the level of acceptability of mobility and travel choices were also assessed [23]. Pricing measures have been tested and implemented in many case studies to influence travel behaviour and shift travellers to more sustainable options of travel since the 1980s [46,50]. The study studied public acceptability of road pricing in Norway and impacts on travel behaviour. The Swedish congestion charging scheme was assessed ten years after its first implementation [51,52], and it was found that pricing charges had a positive impact on reducing traffic congestion and that larger impacts on travel behaviour were observed when it was first introduced. The study authors also assessed and demonstrated the impacts of congestion pricing and its level of acceptability.

The above literature review has demonstrated the influence of social factors, attitudes, environmental factors, sustainability and forms of TDM measures on public acceptability of such measures. Their impacts on modal choice, travel behaviour and attitudes are evident and plentiful. What is not evident yet, however, is the relevance of these measures and their influence on travel behaviour in countries such as KSA, where a majority of the population have no experience with using public transportation and all their travel is through many

forms of private transport options. In this case, it is not clear how effective road pricing would be, whether any pricing measures would be publicly acceptable, or supported, and what the purposes would be.

3. Methodology

3.1. Experiment Design

In this research it is intended to assess the attitudes towards the choice of mode of travel and the potential public support of road pricing measures for the aim of achieving a more sustainable transportation system. An online survey was designed and sent to more than 2000 participants in order to maximise the response rate. This is because travel surveys are not very common yet in the KSA and it was expected that the response will be low. Furthermore, the study was designed to investigate road pricing; therefore, all participants who were included in the analysis have reported that they were familiar with the principles of road pricing. Any participant who was not familiar with road pricing was not included in the study. The aim was to achieve about 500 responses; however, only 399 completed questionnaires were obtained over the period from August to November 2022. This was discussed and a decision was made to accept this sample and carry out the analysis, since the main aim here was to get an understanding of the overall acceptability of pricing measures in the KSA and to get an insight into how to go ahead further with similar studies. Therefore, the sample was considered to be adequate.

The questionnaire included, among other information, the following:

1. Participants' modes of travel;
2. Journey characteristics;
3. Family characteristics;
4. Reported personal travel characteristics;
5. Attitudes towards TDM measures;
6. Attitudinal questions towards the transportation system in Riyadh;
7. Attitudinal questions towards the importance of factors related to the transportation system (safety, reliability, delays, congestion, . . .);
8. Socio-economic characteristics.

In this paper, information obtained from items 1–5 and 8 have been analysed as discussed later. Information obtained from items 6 and 7 will be analysed and reported in future publications.

In terms of the meaning of road pricing, all that was needed in this case was that the participant would be familiar with the term and meaning of road pricing in its general terms. The participants were initially asked if they were familiar with the principle of pricing the roads to achieve some traffic or environmental objectives. All participants that were included in the analysis did answer "yes" and stated that they were familiar. Any participant who was not familiar with the principle of road pricing was not included in the analysis. The participants were then asked to express their support for road pricing measures on a three-point Likert scale {disagree, not sure, agree} or {1, 2, 3}. They were asked: "Would you be in favour of charging motorists to enter the city if the revenue raised was spent on:" and offered three options as answers: "Reducing congestion, improving road safety and reducing travel times". The responses were analysed and discussed in relation to social economic characteristics (gender, marital status, position in the family and income). These responses were also included in a mode choice model for travel including mainly all forms of private cars (private car, shared private car, private driver, private business driver, contracted driver). The three options of PT, cycling and walking were excluded from the further analysis, as they represent a very small proportion of the population.

3.2. General Analysis

In the general analysis section, the socio-economic characters of the sampled participants will be presented.

3.3. Attitudinal Analysis

The attitudes towards road pricing will be investigated against three programs:

a. reducing traffic congestion in the city;
b. improving road safety in the city;
c. reducing travel time in the city.

3.4. The Analytical Model

The behaviour of a traveller in terms of selecting the mode of travel will be modelled as a multinomial discrete decision using the random utility framework. Random utility models (RUM) postulate that decision-makers facing the problem of choosing among a discrete set of alternatives will select the one alternative with the maximum utility. However, utilities are not perfectly the same for all decision-makers and/or they are not completely known to the modeller. Variations amongst the subjects and non-perfect knowledge is taken into account in the RUM by assuming that the utility of the alternative i function for the decision maker q is equal to:

$$U_{iq} = V_{iq} + \varepsilon_i \quad (1)$$

where V_{iq} is the utility's systematic component and ε_i is the random component. Generally, the systematic component is a deterministic function of the attributes of option *i* and the characteristics of the decision-maker. The data collected are usually analysed and tested to identify the relevant variables to be included in the utility function.

In this case, a logistic regression model [53] was calibrated. The travel options that were included comprise the private car, the shared private car, the private driver, the private business driver, and the contracted driver. In the analysis, we assume that the traveller considers which mode to use, subject to a set of independent variables which include the participants' socio-economic characteristics, the transport system characteristics as well as the attitudinal responses towards road pricing programs. The dependent variable is equal to 1 when the decision-maker decides to use a particular option, and 0 otherwise. In our analysis, the parameters of the utility function for the choice of each of the five main modes of urban travel in Riyadh were estimated using a Multinomial Logit Model (MLM).

It should be noted here that the survey data include questions on general characteristics of the participant including socio-economic characteristics, attitudes towards road pricing, travel characteristics and attitudinal characteristics. The validity and reliability of the survey and the responses were tested; the validity of the survey was guaranteed, as there were two sets of calibrated indicators using the data sets, including for examples responses from gender categories, position in the family and marital status. Each two sets of results were almost very comparable, which was reassuring as a validity test. For reliability reassurances, the test–retest method was used. The survey was carried out with a small set of samples, then repeated on the same set, and the results were verified to show similar responses. The small samples were informed and agreed that the survey will be repeated on them a week later.

4. General Analysis of the Results

The general analysis of the data is presented in Table 1 below, which summarises the socio-economic characters of the participants. These include gender, position in the family, marital status and income. The data was obtained from a completed 399 surveys.

Table 1. General statistics of the participants' socio-economic characters.

Variable	Surveyed	%
Gender		
Male	183	45.86
Female	216	54.14
Position in the HH		
Son	84	21.1
Daughter	162	40.6
Husband	99	24.8
Wife	54	13.5
Marital Status		
Single	228	57%
Married	144	36%
Divorced	21	5%
Widowed	6	2%
Income (individual income per month)		
High (>20 K SR/m)	144	36.09%
Medium (12–20 K SR/m)	99	24.81%
Low (5–12 K SR/m)	117	29.32%
V Low (<5 K SR/m)	39	9.77%

From the Table 1, it appears that 54.14% of participants are females while 45.86% are males. With regarding to the participants' position in the family, the results show that 40.60% of the sample fall in the "daughter" category. A total of 24.81% of the sample are "husband", 21.05% are "sons", while only 13.53% are "wives". In terms of marital status, 57% of the sample are singles, 36% are married, 5% are divorced and 2% are widowed.

Four income groups are defined in this survey: over 36% of the participants fall in the highest income group (>20,000 SR, which is the equivalent of (>5300 USD). About 24% of participants fall in the next largest income group category (12,000–20,000 SR (3200–5300 USD)). The next income group (5000–12,000 SR (1330–3200 USD)) is represented by just over 29% of participants, and the final category represents only 9% of participants, with a monthly income < SR 5000.

5. Attitudinal Analysis towards Pricing Policies

The participants' views on road pricing measures were investigated under three scenarios: "Road pricing measures to reduce traffic congestion in the city", "road pricing measures to improve road safety in the city" and "road pricing measures to reduce travel time in the city". For each of these scenarios, the responses were reported on a three-point Likert scale {1, 2, 3}. The results are analysed and discussed below.

5.1. Road Pricing to Reduce Congestion in the City

The participants were asked to express their attitudes towards the statement: "Road pricing will be an effective measure to reduce congestion in the city". A percentage of 38.3% of participants reported that they do not agree with that statement, 36.0% reported that they do agree that pricing measures are effective at reducing congestion in the city, while 25.6% of participants reported that pricing measures may be effective (Table 2 below). The examination was also carried out in association with the socio-economic characteristics of the participants. The results show that male participants and single participants were the most supportive of the pricing measure for congestion reduction purpose (about 45%

of each of the male and the singles groups showed support for the measure). In terms of income groups, the highest support (42%) was observed from the highest income group which is (>20,000 SR per month). Within the position in the family, the sons and the husbands show the highest support (48% of all sons and 60% of all husbands support the measure). It should also be noted, however, that while there is about 40% overall support for pricing measures for congestion reduction, there is also about 50% disagreement on this measure. This is expected, as road pricing is a new concept in the KSA.

Table 2. Total number and percentages of level of agreement towards road pricing for the three objectives.

Attitudes towards Road Pricing	Agree that Pricing Measures Will Achieve the Objective	Maybe Agree that Pricing Measures Will Achieve the Objective	Do Not Agree that Pricing Measures Will Achieve the Objective
for the objective of reducing congestion in the city	144 (36.0%)	102 (25.6%)	153 (38.3%)
for the objective of improving road safety	273 (68.4%)	75 (18.8%)	51 (12.8%)
for the objective of reducing travel time	159 (39.8%)	114 (28.6%)	126 (31.6%)

Figure 1 shows the percentage responses of the participants to the question of whether road pricing is an effective measure to reduce traffic congestion, improve road safety and reduce travel times. Tables 2 and 3 show the responses with consideration of the socio-economic characteristics. Figure 2 shows the responses to road pricing as an effective measure to reduce congestion in the city classified by socio-economic characteristics.

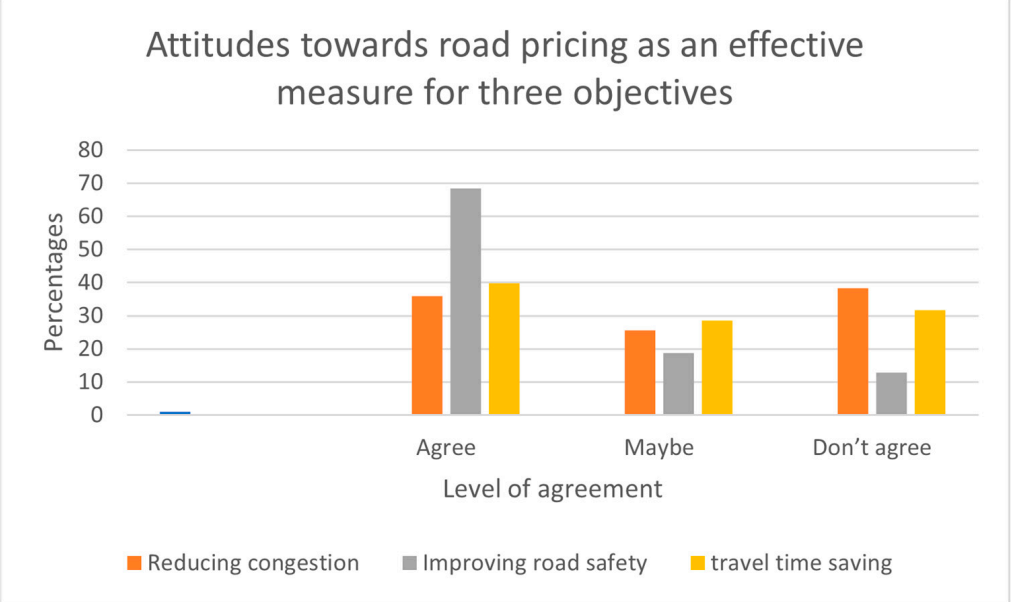

Figure 1. Percentage responses of the participants to question of whether road pricing is an effective measure to reduce traffic congestion, improve road safety and reduce travel times.

Table 3. Attitudes towards road pricing and socio-economic factors.

	Gender		Marital Status		Income Categories (SR)				Position in Family			
	Male	**Female**	**Married**	**Single**	**>20 K**	**12–20 K**	**5–12 K**	**<5 K**	**Son**	**Daughter**	**Husband**	**Wife**
Congestion reduction												
Agree	81	63	51	78	64	38	30	12	36	42	48	18
Disagree	30	72	21	77	22	37	34	9	21	60	9	12
Maybe	72	81	72	78	61	23	49	20	25	57	47	24
Improve road safety												
Agree	111	162	103	164	101	55	93	24	46	119	67	41
Disagree	42	33	24	38	27	20	12	16	25	28	15	7
Maybe	30	21	17	31	19	23	8	1	11	12	22	6
Travel time saving												
Agree	69	90	48	104	74	40	33	12	36	69	33	21
Disagree	45	69	30	75	36	28	28	22	22	56	21	15
Maybe	69	57	66	54	37	30	52	7	24	34	50	18
Total	183	216	144	233	147	98	113	41	82	159	104	54

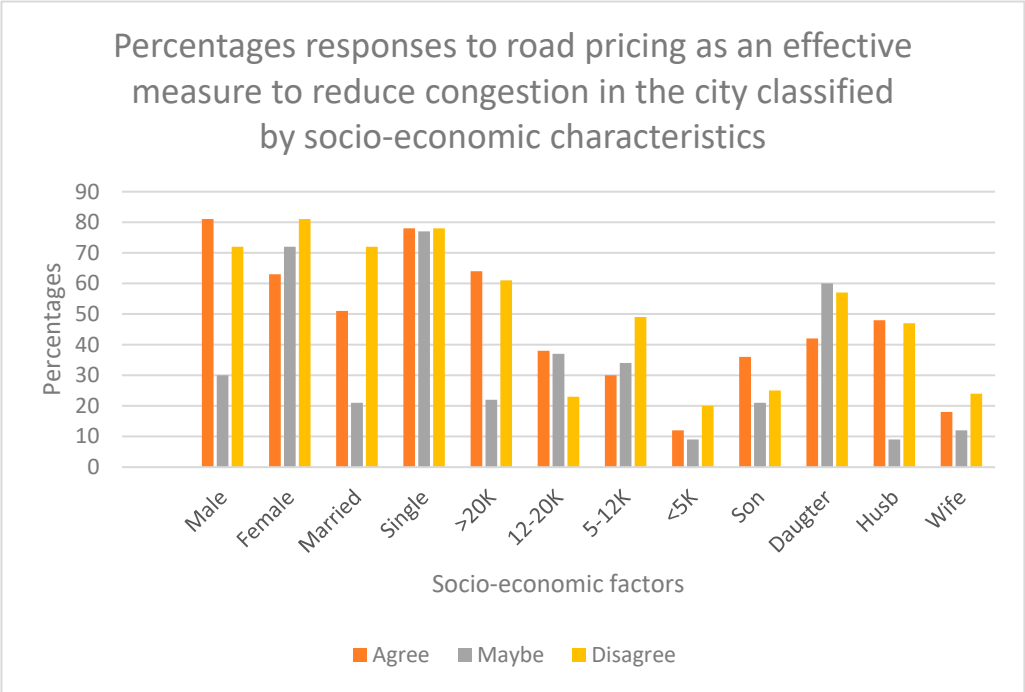

Figure 2. Responses to road pricing as an effective measure to reduce congestion in the city classified by socio-economic characteristics.

5.2. Road Pricing Will Be an Effective Measure to Improve Road Safety

The participants were then asked to express their support for pricing measures to achieve improved road safety of the transportation system (i.e., high charges for those who break traffic safety regulations). This may include higher fines for speeding, for example. A percentage of 68.4% reported their support for the pricing measure for road safety, 18.8% said maybe they would support, while only about 13% reported that they do not support the pricing for the purpose of safety concerns. Figure 3 shows the responses of the participants regarding road pricing as an effective measure to improve road safety.

From the figure, it is obvious that the level of support for pricing measures is higher when the aim is to improve road safety than where the aim is to reduce traffic congestion. This finding has important implications for policymakers when designing pricing measures and programs in the Kingdom.

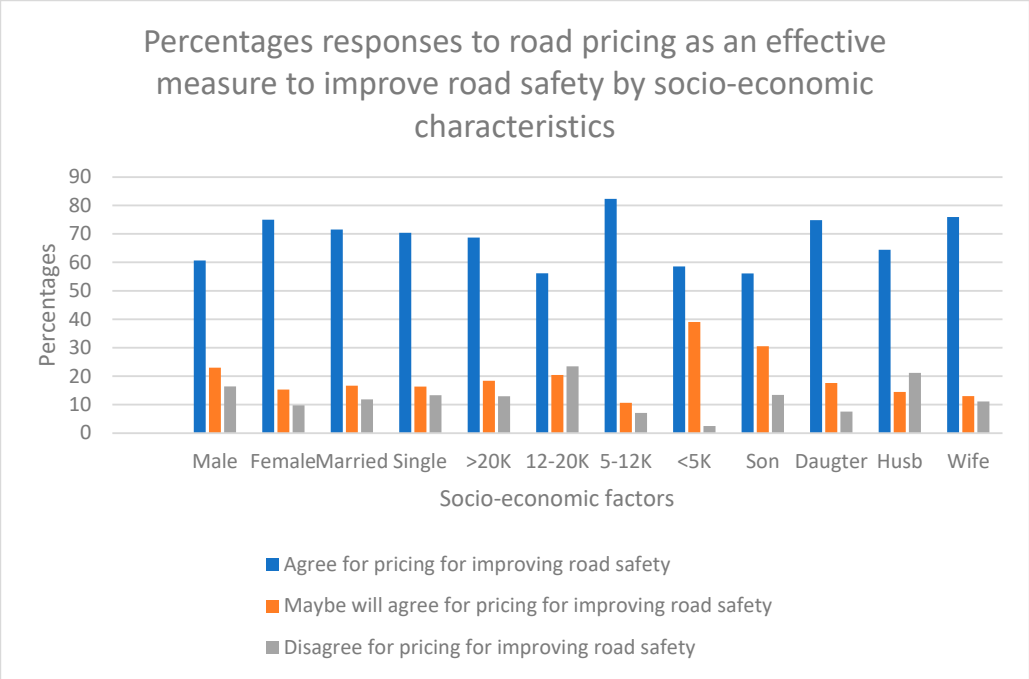

Figure 3. Responses to road pricing as an effective measure to improve road safety in the city.

5.3. Road Pricing Will Be an Effective Measure to Reduce Travel Time

On the other hand, when asked about their acceptance of pricing measures in the city for the purpose of reducing travel times, the responses were very different. About 40% agreed, 32% disagreed while 29% were not sure. The responses show that more females (about 42% of females) than males (about 37% of males) support pricing measures for reducing travel time. On the other hand, about 37% of males were against pricing measures to reduce travel times. This might suggest that females value time more highly than males, which is evident in many other societies [54].

Regarding marital status, the statistics show that single participants were more supportive of pricing measures to save time (46%) than the three other categories* in the martial status category. In terms of income impacts on responses towards pricing measures for the aim of reducing travel time, the results show that the higher the income group category, the higher the support for pricing measures to reduce travel time (about 52% of the highest income group supported pricing for the aim of reducing travel time, while only 28% of the lowest income group category (<5000 SR) supported this measure.

When the data was classified according to position in the family, the most support for pricing measures for reducing travel time were obtained from the son and daughters relative to the husband and wife. This might also reflect impacts of age groups and that the younger generation are keener to save time than their older counterparts (42% support from the younger generation versus 33% and 38% support from the husbands and wives, respectively).

Figure 4 shows the responses of the participants for road pricing as an effective measure to reduce travel times with their classifications according to the main characteristics of the participants, respectively.

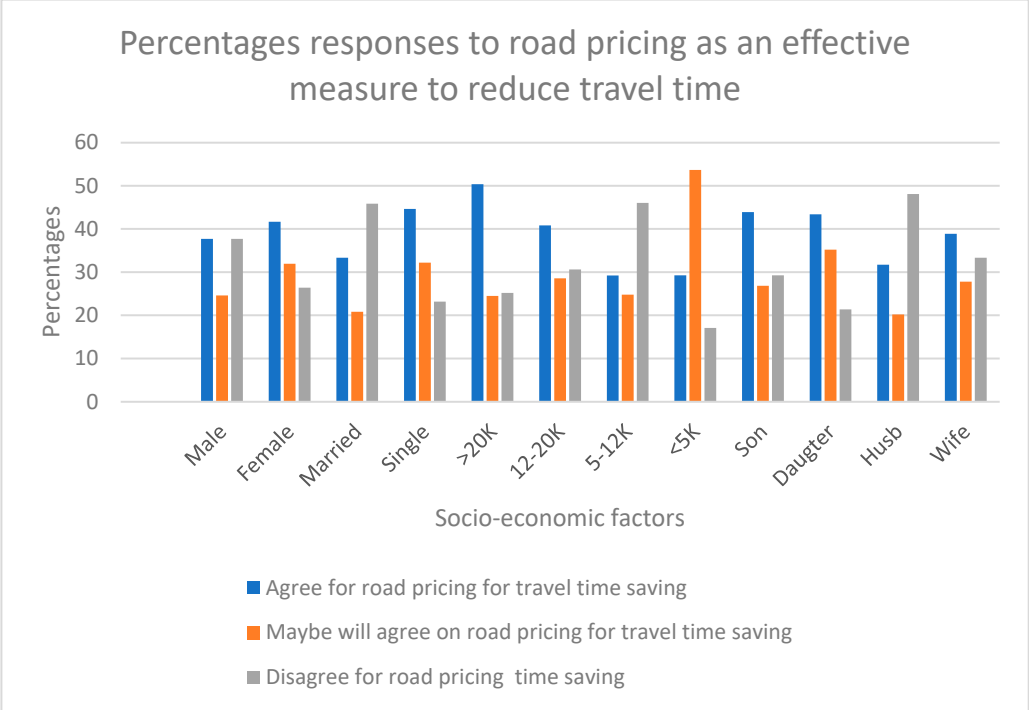

Figure 4. Responses to road pricing as an effective measure for reducing travel time in the city classified by socio-economic characteristics.

To conclude, the overall support for the pricing measures was seen to be at its highest towards measures that improve safety. Higher income groups and the male members of the family were keener on reducing congestion than those with lower incomes. Women are keener on reducing travel time than their counterparts, the men. The next section presents the results of modal choice analysis.

6. Mode Choice Statistics

6.1. General Statistics

In the survey, the participants were asked to report on the most frequently used mode of travel. Figure 5 and Table 4 below show the definition of each mode of travel and the distribution of the sample amongst the available modes of travel. From the results, it is obvious that the private car is the most dominant mode of travel, with over 42% of participants reporting it to be their most used option of travel. Over 17% of participants reported that they use shared cars. This is a very common mode of travel in KSA, where members of the family share a ride. For example, a father or a son would give another member of the family a ride to school, college or place of work. Private drivers are also a common means of travel in KSA, although it is claimed that their numbers have decreased a lot since women started driving in the Kingdom in 2018. From the survey results, 14% of the participants use private drivers while another 7% ride with private business drivers. Travelling with a taxi or a daily or monthly contracted driver is also a very common means of travel in the Kingdom, where mostly individuals who do not own a private car contract a private driver to drive them to and from work or for any non-work single or regular trips. The pay in this case is negotiable and agreed. In this survey, just over 14% of participants reported hiring a contracted driver. Walking and using public modes of travel represent just over 2% each of the total travel.

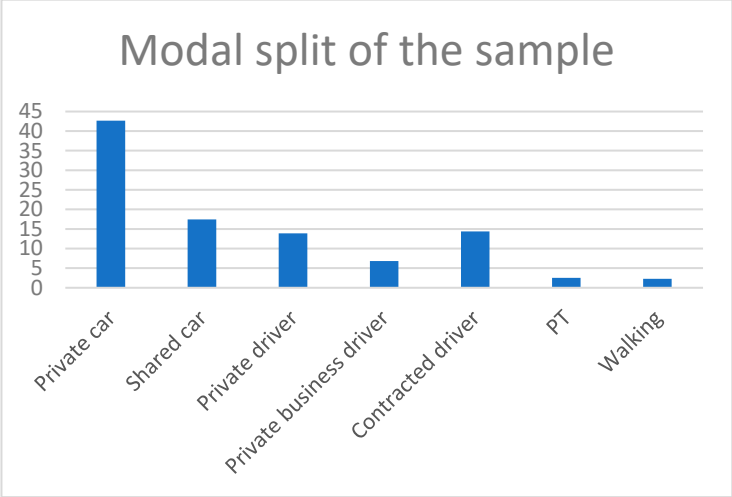

Figure 5. Modal split of the sample.

Table 4. Modal split numbers and percentages.

Mode of Travel	Description	Number of Participants	Percentages
Private car	A ride in a privately owned and operated car	169	42.67%
Shared car	A ride with another member of the family or friend in a private car	69	17.42%
Private driver	A ride with a driver who is employed by the person/family	55	13.88%
Private business driver	A ride with a driver who is employed for the individual person by his employer/business	27	6.82%
Contracted driver (a taxi service)	A ride with a taxi driver who is contracted for specific regular trips (e.g., drive children to schools or women to their workplaces) for a limited period of time	57	14.39%
	A ride with a taxi driver who is hired for a specific single trip (e.g., drive an individual to work or shopping). However, this form of service has now been reduced a lot and replaced by the like of Uber's services.		
PT	A ride in a public bus or a metro	10	2.52%
Walking	--	9	2.27%

Other factors that seem to affect mode choices include position of participant in the family, income level, gender, travel time and travel cost. The definitions of these variables that have been included in the model are presented in Table 5.

Table 5. Variables' definitions.

Variable	Definition
IVT	In vehicle travel time in minutes
Cost	Number of fueling/months
Pricing to reduce traffic congestion	Level of support for pricing measures to reduce traffic congestion {1, 2, 3}
Pricing to improve road safety	Level of support for pricing measures to improve road safety {1, 2, 3}
Pricing to reduce travel time	Level of support for pricing measures to reduce travel time {1, 2, 3}

Table 5. *Cont.*

Variable	Definition
Gender	Gender of participants (Male)
	Female (reference category)
Marital status	Single
	Married (reference category)
Position in family	Son
	Daughter
	Husband
	Wife (Reference category)
Income	<5000 SR/Month (Reference category)
	5000–12,000 SR/Month
	12,000–20,000 SR/Month
	>20,000 SR/Month

6.2. Modelling Modal Choice in Riyadh

Using the survey data, the parameters' coefficients of the utility function of a Multinomial Logit Model (MLM) for the choice of each of the five main modes of urban travel in Riyadh have been estimated. A separate model has been calibrated for each of the modes of travel; the private car, shared car, private driver, private business driver and a taxi or contracted driver. The other options of travel, such as public transportation, walking and cycling, were not included further in the analysis as they were only used by a very small proportion of participants. Table 6 below shows the coefficient estimates with *t*-values in brackets and the general statistics of the model.

Table 6. Coefficient estimates, *t*-values and general statistics of the model.

Variable/Name	Models' Coefficient (*t*-Statistics)				
	Private Car	**Shared Car**	**Private Driver**	**Private Business Driver**	**Contracted Driver/Taxi**
IVT	−0.05111 (−2.9102)	−0.0392 (−2.981)	−0.058 (−4.1620)	−0.0410 (−4.1703)	−0.07110 (−4.0748)
Cost	−0.0352 (−2.734)	−0.0287 (−1.980)	−0.0431 (−3.324)	−0.0786 (−5.713)	−0.0823 (−3.765)
Gender					
Male	0.412 (2.923)	−0.736 (−2.876)	−0.5421 (−4.112)	0.816 (3.321)	−0.023 (−4.165)
Female (Reference category)	0.00	0.00	0.00	0.00	0.00
Marital status					
(Single)	−0.1491 (−1.816)	0.1360 (2.110)	−0.254 (−1.99)	−0.471 (−2.101)	−0.178 (−2.120)
Marital status Married (Reference category)	0.00	0.00	0.00	0.00	0.00

Table 6. *Cont.*

Variable/Name	Models' Coefficient (*t*-Statistics)				
	Private Car	**Shared Car**	**Private Driver**	**Private Business Driver**	**Contracted Driver/Taxi**
Position in family					
Son	0.234 (3.248)	−0.315 (−2.981)	−0.534 (−2.098)	0.053 (3.521)	−0.285 (−4.001)
Daughter	−0.354 (−1.78)	0.024 (2.761)	−0.165 (−2.076)	−0.037 (−3.013)	−0.089 (−2.911)
Husband	0.481 (2.671)	−0.324 (−3.651)	−0.623 (−2.810)	0.283 (3.651)	−0.701 (−4.110)
Wife (Reference category)	0.00	0.00	0.00	0.00	0.00
Income					
<5000 SR/Month (Reference category)	0.00	0.00	0.00	0.00	0.00
5000–12,000 SR/Month	0.016 (3.110)	−0.024 (−2.813)	0.135 (3.018)	0.182 (2.965)	−0.0127 (−3.278)
12,000–20,000 SR/Month	0.321 (2.987)	−0.413 (−3.282)	0.287 (3.789)	0.382 (2.345)	−0.121 (−4.102)
>20,000 SR/Month	0.414 (2.234)	−0.436 (−2.898)	0.354 (3.265)	0.501 (3.987)	−0.315 (−2.345)
Attitudes towards pricing measures for the aim of:					
Reducing congestion	0.0621 (2.802)	0.0412 (2.891)	0.061 (4.2630)	0.0698 (3.1703)	0.0832 (4.0748)
Improving safety	0.0432 (2.814)	0.0797 (2.011)	0.0391 (3.412)	0.0566 (5.803)	0.0879 (3.699)
Reducing travel time	0.0672 (2.814)	0.0411 (2.012)	0.0623 (4.123)	0.0786 (5.891)	0.0523 (4.213)

Observations: 399 L(0) = −1702.656; L(M) = −1181.320; R^2 = 0.3199.

6.3. Discussions of the Results

From Table 6, all variables included in the model have *t*-values greater than ±1.99 and their inclusion in the model increases the R-squared as well as the measures of goodness of fit, including the likelihood for a model with only a constant (L(0)) and the final likelihood for the proposed model. Tests were run to check if there were large interactions between the two variables related to the decision-makers' age and position in the family. Accordingly, the age variable was excluded and only the position in the family was included, since it does reflect the age of participants as well as their position in the family.

Given the definition of the independent variables in Table 5, positive coefficients indicate that a variable increases the probability of using the specified mode of travel while negative coefficients indicate a reduction in the probability of using it. For example, the "IVT" and cost variables are both statistically significant with negative signs indicating a reduction in the probability of using the specified modes of travel with an increase in their values. Regarding the position in the family, the wife seems to capture the highest position as a rider with a taxi or contracted driver and also as rider with a private driver.

While Saudi women started driving their own cars recently, since 2018, and the number of female drivers is sharply increasing, it is obvious that the male members of the family (husbands and sons) are still dominating the private car option. This finding is supported by a positive sign for the gender "male" relative to the reference category "female", while

having negative coefficients for each of the shared car and the taxi/contracted driver. The male members of the family are also associated with positive coefficients with the private business driver. Finally, the income category > 20,000 SR/month has the highest positive coefficients associated with travelling by private car, with a private driver and a business driver over the other income groups, while having negative coefficients associated with travelling by a taxi or contracted driver or car sharing.

Regarding the attitudinal variables, all the coefficients have positive signs. This indicates that the choice of the specific travel option is associated with positive attitudes towards the specific measure. For example, all reducing-congestion parameters have positive coefficients, and the highest values of these were associated with the private car as a mode and then the option of a private driver and a private business driver. Accepting road pricing for the aim of improving safety parameters was also calibrated with positive coefficients; the largest values of these coefficients were associated with the shared vehicles and with the contracted driver options. It is worth mentioning that those two options are mostly used by women (wives and daughters), as discussed earlier. This might be an indication of the fact that women attach a higher value to road safety than men. Thirdly, the coefficients of road pricing for the aim of reducing travel time were also calibrated and all have a positive sign. The highest values of these were associated with the private, private business and the contracted drivers. This might reflect the level of importance of reducing travel time that is associated with the relatively higher income group (i.e., the private car, the private and private business) participants.

7. Conclusions

The main aim of the study is to assess the public acceptability of road pricing, in its general form in the Kingdom of Saudi Arabia. Road pricing is a travel demand management (TDM) measure that has been discussed, investigated, implemented and proved successful in many world cities in order to reduce congestion and improve the environment [55,56]. The KSA is a rich country, and the private car is the dominant mode of travel since there is very low provision of public travel options and due to cultural considerations. The Kingdom of Saudi Arabia (KSA) is entering a new era of national reform and support of sustainable measures that aim at reducing congestion, reducing air pollution and achieving better air and environmental qualities is gaining a vast momentum in the country.

It is generally recognized that transport is a key contributor to global CO_2 emissions and to negative impacts on the environment. Measures and actions that aim at reducing these negative impacts have been widely adopted by many and include boosting public transportation systems. In the KSA, the use of public modes of travel was not strongly developed in the country due to a number of factors including cultural as well as the low provision of such options. Riyadh city is in the process of finalising a massive metro project that will open in 2023, and the city is therefore looking at implementing measures and programs that would aim at supporting the metro system. In order to encourage sustainable travel, it is important to provide public transportation options as well as implement disincentives for private car usage. The concept of implementing TDM measures to reduce demand on the private car is new in the KSA, and therefore there is a lot to be learned and studied in this area. The acceptability of pricing policies, which proved successful in many other world cities, is also still to be tested and assessed in the KSA.

The study analysed data that have been collected using an online survey in Riyadh city, including data on the preferences and attitudes towards road pricing. While the sample size is slightly low in this survey (399 completed surveys), to allow the generalisation of the results to the whole city of Riyadh and other cities in Saudi Arabia, the methodology has given an insight into how to go ahead further with the design of TDM measures. The results show an overall support for pricing measures. The results also show that the level of support for road pricing increases significantly when the aim of this measure is clear and associated with an important subject. In this case, a large support has been ascertained towards road safety. Female members of the sample have been most supportive of the

pricing measures for the aim of improving road safety. Previous research showed that road pricing is highly accepted when the aim is to achieve an efficient transport system rather than to raise revenues. Experience from previous practices shows that the aim of the pricing scheme is to influence its acceptability [55]. For example, pricing measures were rejected in cases where there were already efficient public transportation systems that are successful and used heavily, as in the case of Kristiansand city in Norway in 1988 [56].

The survey outcomes also show that car ownership and use are still very high in the country. However, women, who just started driving five years ago, are almost sharing the roads of the Kingdom equally with men. The results show that 44% of the 70% private car travellers are women while 56% are men. Most high-income participants have also reported that they mainly use their private cars. Lower-income participants and women, in particular, rely mostly on the taxi or the contracted driver. Using a private driver is still a very popular means of travel in the Kingdom and is almost equally used by women and men.

Analysis of who responded to the proposed pricing measures for the purpose of reducing travel time indicated that more females than males (42% of females and 37% of males) supporting pricing measures for saving time. On the other hand, another 37% of males were against pricing measures to reduce travel times. This might suggest that females value time more highly than males, which is evident in many other societies [54]. Finally, results of a modal choice model show that all variables of the model have *t*-values greater than ± 1.99 and that their inclusion in the model increases the R-squared as well as the measures of goodness of fit, including the likelihood for a model with only a constant (L(0)) and the final likelihood for the proposed model. Negative coefficients are associated with "IVT" and cost variables indicating a reduction in the probability of using the specified modes of travel with an increase in their values. Regarding the position in the family, the wife seems to be capturing the highest position as a rider with a taxi or contracted driver and also as a rider with a private driver. Further, more in-depth investigations and sensitivity analysis of IVT, cost, and income, are recommended for future research, since these parameters may well affect the transport policy and TDM measures.

This research is very timely, as the KSA is at the stage of adoption of TDM measures that can be used to achieve sustainability and realise the new national visions. The implementation of TDM measures appears to be the most effective when targeting important aims such as road safety and reducing congestion. It is, therefore, very important to understand the preferences and the level of public support for the various TDM measures before planning for their implementation. In addition, raising awareness of the population about the importance of public transportation as a travel option is equally important. Studies for raising awareness and demonstrations to clarify the benefits of such measures are immediately needed in KSA and other similar countries.

8. Limitations

This research took place in the city of Riyadh, the capital city of the Kingdom of Saudi Arabia. Riyadh has witnessed fast development and advancement in the country over the past decade or so. Travel behaviour and attitudes in other cities of the Kingdom are also very relevant and important and must be investigated. The sample size that was obtained in this research was limited to 399 participants. While this is a good sample to obtain statistically significant results, obviously larger samples can provide more information and understanding of attitudes and behaviour; further research with larger samples would be encouraged. The study has also been limited to developing a multinomial logit model. Other more generalised types of models can also be calibrated, tested and compared. Future research on other relevant issues, such as values of travel times, progression of travel behaviour and choices, safety issues that relate to travel options, raising awareness of travellers and other population groups of relevance and the importance of sustainable behaviour is also relevant and immediately needed. Finally, women's issues have been touched on briefly in this study. Further in-depth investigations of a number of variables including social-economic and travel characteristics, such as IVT, cost, income, and employ-

ment need addressing and considerations in further research, since all these parameters will affect the transport plans and strategies and relevant TDM measures.

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