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The Role of Quality, Planning, and Cost Management on Project Management an Empirical Study of The Riyadh Metro Projects in Riyadh City, Kingdom of Saudi Arabia

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Dedication

This research project is dedicated to my wife, whose unwavering love and support have been the driving force behind my academic pursuits. Her encouragement and belief in me have been a constant source of inspiration, and I am forever grateful for her guidance and wisdom. I look forward to attending the graduation ceremony with you.

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Abstract

We carried out this study to look into the impact of traffic management initiatives on Riyadh Metro projects. Transportation is a problem that necessitates continuous movement, which leads to conflicts, friction, and crashes. The responsible authorities need to control the situation regarding road conditions, car quality, driving behavior, and pressures on the surrounding demographic and geographic areas as the number rises. Nowadays, Riyadh stands among the most car-clogged cities in the Arab and worldwide worlds. There is little doubt that traffic congestion has worsened as a result of the high standard of life, which has led to each family owning many cars. It is undeniable that several sectors play a part in paving roads, building bridges, transporting vehicles, and delivering these services, but the crucial distinction was When the Riyadh metro system is implemented as a sustainable transportation option that would provide inexpensive, convenient, and dependable urban mobility, the study's significance resides in bringing to light a crucial issue. We spoke with residents of Riyadh firsthand to learn how they deal with the everyday traffic. We distributed a survey to various parent groups on What's App and to many work groups; many of them messaged us in addition to responding to the survey. A group sample of parents and workers in Riyadh City received the survey; all our informants were kept anonymous. Among our inquiries were:

What are the causes of traffic in Riyadh? Who is responsible for this traffic?

What are the solutions in your opinion? Why is he responsible for the traffic in Riyadh?

Our intention in interacting with various citizen types was to extract possibly divergent viewpoints rather than obtain a representative sample of the Whats App groupings. We can determine the number of persons who viewed our survey in light of the previously described problems. Through exchanged messages, we obtained 8 responses to our questions from over 300 people. The replies we got showed a wide range of viewpoints regarding the target demographic. Even though we are able to measure the audience's perspective on the matter, the responses we got offer insightful information about some fundamental distinctions in audience conception. Subsequent research studies could investigate the frequency of these responses and their correlation with population figures, demography, or socioeconomic standing.

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One strand of research has focused on the barriers and bridges to certain modes of transport. Derek Halden Consultancy (2003) examine car users' barriers to switching to the metro, BRT, walking or bicycling, and identify bridges that enable this switch. Blainey, Hickford, and Preston (2012) show that even when rail travel is the most cost-effective transport mode for a particular journey, many travelers still choose other modes. Thus, non-financial barriers to choosing rail transport exist. Blainey, Hickford, and Preston (2012) identify 37 distinct barriers divided into three broad groups,

Figure 1. Thirty-seven distinct barriers to modal shifts to rail.



Source: Blainey, Hickford, and Preston (2012).

as Figure 1 shows. These groups represent hard barriers (e.g., travel time, reliability and cost), soft barriers (e.g., comfort, information and security) and complementary barriers (e.g., weather and

lifestyle). However, the concepts of ‘hard’ and ‘soft’ factors or measures are not yet clearly defined.

A consensus has formed that the former are more related to indicators and interventions on the supply side of the transport system. In contrast, the latter are more related to the demand side, which includes psychological and behavioral strategies (Queiroz, Celeste, and Moura 2020). Blainey, Hickford, and

Preston (2012) also identify four types of bridges. These are enhancing alternative modes, making car travel less attractive, ensuring efficient management and administration, and providing information on available modes.

Other studies have found that individuals’ socioeconomic characteristics strongly affect their mode choices (Limtanakool, Dijst, and Schwanen 2006; Munshi 2016). For instance, income, car ownership, gender, age, household composition and lifestyle are robust and relevant predictors of mode

Figure 1. Thirty-seven distinct barriers to modal shifts to rail.

Source: Blainey, Hickford, and Preston (2012).

List of tables

Table 1. Independent variables in the utility function and sample description.

Descriptive statistics of choice attributes	Sample: Car to metro		Sample: Taxi to metro	
Total observations	1,332		432	
Choice attributes	Car mean (sd)	Metro mean (sd)	Taxi mean (sd)	Metro mean (sd)
Walk time to access the transit mode	4.05 (3.22)	6.43 (3.96)	2.94 (1.18)	11.27 (3.10)
Wait time for the transit mode	0 (0)	4.43 (2.20)	2.98 (1.22)	4.33 (2.06)
Travel time for the transit mode	33.50 (18.29)	28.39 (18.94)	24.63 (9.23)	16.63 (9.96)
Cost of the transit mode	12.65 (12.62)	4.83 (1.59)	30.00 (10.86)	5.00 (1.63)
Descriptive statistics of respondents				
Total number of respondents	148		48	
Sociodemographics	Frequency	Percentage	Frequency	Percentage
Age: Younger than 30 years	75	50.7	23	47.9
Age: 30 to 45 years	59	39.9	19	39.6
Age: 45 years or older	14	9.5	6	12.5
Nationality: Non-Saudi	63	42.6	0	0.0
Nationality: Saudi	85	57.4	48	100.0
Education level: Low	27	18.2	14	29.2
Education level: Intermediate	50	33.8	19	39.6
Education level: High	71	48.0	15	31.3
Employment status: Employed	109	73.6	24	50.0
Employment status: Student	27	18.2	18	37.5
Employment status: Retired	2	1.4	3	6.3
Employment status: Looking for work	10	6.8	3	6.3
Marital status: No	74	50.0	19	39.6
Marital status: Yes	74	50.0	29	60.4
Family type: Single person	23	15.5	9	18.8
Family type: Nuclear family	112	75.7	38	79.2
Family type: Extended family	9	6.1	1	2.1
Family type: Other types	4	2.7	0	0.0

More than one household car: No	59	39.9	24	50.0
More than one household car: Yes	89	60.1	24	50.0
Travel purpose: Work	61	41.2	3	6.3
Travel purpose: Shopping	28	18.9	8	16.7
Travel purpose: Personal business	8	5.4	12	25.0
Travel purpose: Social and recreation	32	21.6	6	12.5
Travel purpose: Medical	2	1.4	6	12.5
Travel purpose: School	6	4.1	6	12.5
Travel purpose: Others	11	7.4	7	14.6

Source: Authors.

Table 1 summarizes the basic statistics for our sample data based on the travel mode. We consider age, nationality, educational level, employment status, marital status, family type, car ownership and trip purpose. The majority of respondents use cars for work trips, whereas taxis are used most frequently for personal business trips. Almost 50% of car users are well educated (i.e., hold a bachelor's degree, master's degree or Ph.D.). The highest proportion of taxi users have an

intermediate level of education. Most respondents were employed, followed by students. Approximately 57% of car users are Saudi citizens, whereas non-Saudis are found less taxi users. Over 40% of trips are work trips by car, whereas the majority of taxi trips are personal business trips, followed by shopping and recreation trips. The majority of the respondents were from nuclear families.

Table 1 also provides the mean and standard deviation of travel cost, travel time, wait time and walk time for a one-way trip. Taxis are the most expensive, whereas car trips have the longest travel times. The survey asked respondents to compare the metro's travel time, cost, walk time and wait time to their current modes. For modeling purposes, however, we use data reflecting the values for each mode rather than in comparison with the current mode.

Finally, a limitation of the data is the small sample size. However, the data are the only available official data from the Riyadh planning authority. As they are official survey data, they are assumed to be reliable. We apply a sufficient modeling approach to achieve robust results using a small sample size.

Introduction

In this research, I address the topic of The Riyadh Metro projects and although it is a topic that has been extensively researched before by many researchers, I add to them recent growth patterns and future forecasts indicate that Riyadh will have very high population growth rates, which will lead to an increase in the demand for travel on its roadway network and transportation system which is what I focused on due to the connection of this issue with life style in Riyadh city. The study relied on a survey and analytical approach to the factors of quality, planning and cost of transportation and roads and their related factors. The Riyadh metro system is being implemented as a sustainable transport option that will offer reliable, affordable, and comfortable urban mobility. It is important to understand the factors influencing the likelihood that people will use the new metro system. Thus, this study's key objective is to investigate *To investigate the influence of Riyadh Metro projects on managing Riyadh traffic.* We wanted to know what's behind Riyadh's traffic that will influence the choice to use Riyadh's proposed metro system. Giving the Travel times, travel costs, walk times and transfer requirements significantly affect people's mode choices. Travel cost has a greater influence on car users, whereas travel time has a stronger impact on taxi users. Socioeconomic characteristics, such as age, nationality, education level and car ownership also significantly impact the choice to use the metro. The Kingdom of Saudi Arabia has expended considerable efforts to create an energy- efficient urban transport system Such a system can help the Kingdom achieve two important goals. First, the economic sustainability of the energy sector is a top priority for Saudi Arabia as it is one of the world's largest exporters of oil. According to the Saudi Arabian Monetary Agency, approximately 33.42% of the Kingdom's gross domestic product in 2019 was generated by the oil sector (Mahmood, Alkhateeb, and Furqan 2020). Second, achieving the country's net-zero by 2050 target is also a key priority. For instance, the National Renewable Energy Program (NREP) is a strategic initiative of Vision 2030. The program aims to increase the Kingdom's share of renewable energy production, achieve a balance in the mix of local energy sources and fulfill its obligations toward reducing carbon dioxide emissions. Both goals require the country to use all possible strategies to mitigate climate change and achieve energy efficiency. Transportation is a major energy-demanding sector and a major contributor to carbon emissions (Khalili et al. 2019), and is thus gaining importance in the Kingdom's energy policies. Urban transport in Saudi Arabia is predominantly automobile oriented. A shift from automobiles

to public transport can reduce energy demand and carbon emissions and thus improve the country's energy efficiency. However, the urgent need to reduce carbon emissions to mitigate adverse climate impacts requires a drastic shift toward more sustainable modes of transport. According to Kenworthy (2020), public transport can be 55 times more energy efficient than automobile travel. Thus, the Kingdom has proposed a metro system for Riyadh that is currently under development. However, the energy efficiency gains from this system will depend on people's willingness to switch from more traditional car use to metro use. Thus, this study investigates the factors that influence people's willingness to ride the proposed metro. The number of metro systems is increasing globally, societies are becoming more urbanized, and metro systems are critical for mobility. The International Association of Public Transport (2018) notes that at the end of 2017, 178 cities in 56 countries had metros. Moreover, 75 new metros have been constructed since 2000, mainly in Asian countries. Metros transport an average of 168 million passengers per day worldwide (International Association of Public Transport 2018). The growing body of research on metros covers topics ranging from feasibility to operations enhancement and passenger satisfaction. Understanding the necessity of metro systems is helping to accelerate the construction of metro infrastructure. Nonetheless, the modal shift from private cars to metros or bus rapid transit (BRT) is a relatively new research topic. Some recent examples include studies on the proportions of passenger car and motorcycle users shifting to BRT and rail (Kwan, Sutan, and Hashim 2018; Satiennam et al. 2016). Other recent studies analyze the health benefits of BRT (Bartels et al. 2016) and commuters' willingness to shift to the metro (Fraszczuk, Weerawat, and Kirawanich 2019). Anwar and Yang (2017) consider the effects of transport policy on the modal shift from cars to public buses. Krishna, Thomas, and Salini (2020) measure the reduction in fuel consumption and emissions resulting from this modal shift. Mostafi (2022) explores the importance of information and communication technology (ICT)-based mobility services in Cairo. The study examines parameters associated with the frequency of ridesourcing use as well as with the modal shift from different mobility modes, such as from public transport to ridesourcing. Finally, Shaheen and Cohen (2020) investigate mobility on demand and mobility as a service. This study explores people's intentions to shift from their current modes of transport to the metro. Specifically, it considers the proposed new metro system in Riyadh, which includes six lines covering a 176-kilometer network as well as 85 underground, elevated or at-grade section stations (Royal Commission for Riyadh City 2022). The Riyadh metro is intended to achieve the city's

sustainable transport goals. Thus, the factors that influence intention to ride the metro should be explored so that the government can formulate effective transport strategies. This study attempts to provide recommendations for metro stakeholders. The recommendations it provides can help gauge respondents' willingness to shift to the metro and identify the preferred conditions that should be accommodated in planning policies. We also deliver empirical guidelines for understanding customers' perspectives and the mechanisms of shifting from other modes of transport to the metro. These guidelines can eventually be used to meet customer expectations after the new metro system is operational. We aim to understand the underlying factors influencing private transport users' intentions to shift from their current modes of travel to the metro once it becomes available. Using this information, we can better predict the direction of the resulting energy efficiency gains in the urban transport sector.

Research problem

Transportation is an issue that requires constant movement and thus results in friction, collisions, and disputes as well. As the number increases, the competent authority must regulate the situation in terms of the ease of the road, the quality of vehicles, the driving of drivers, and the factors pressing on the geographical and demographic environment.

Research significant

The city of Riyadh has become one of the Arab and international cities most crowded with cars. Due to the high standard of living, which has made each family have more than one car, traffic congestion has therefore increased very clearly. The role of multiple sectors in providing transportation services, vehicular traffic, paving roads, and constructing bridges is not denied, but the vital difference was With the Riyadh metro system when its being implemented as a sustainable transport option that will offer reliable, affordable, and comfortable urban mobility the importance of the study lies in unveiling a vital and extremely important matter.

Research questions

- What is the causes for Riyadh traffic?
- How does the traffic effect the lifestyle in Riyadh city?
- What are the solutions?
- Who is responsible and why?
- What is the impact of The Riyadh Metro projects?
- What are the benefits and drawbacks of The Riyadh Metro projects?

Research objectives

- *To investigate the influence of Riyadh Metro projects on managing Riyadh traffic.*
- *To provide answers on why the problem existed.*
- *To provide solutions*

Research hypotheses

What is the effect of growth of population in Riyadh city on Riyadh traffic jam?

Research model

The capital, Riyadh, is experiencing a difficult state of traffic congestion. This problem threatens human health in this expanding city that is about to increase in population by a million in the coming years due to many considerations, including economic and political ones. What is certain is that traffic congestion threatens its quality of life programs and entertainment and tourism activities for residents and visitors. Some of us have begun to cancel our social connections due to the struggle of reaching the destination within the city. The strange thing is that in recent years, Riyadh has witnessed the construction of main streets in northern Riyadh that are parallel to King Fahd Road. They are supposed to reduce traffic congestion on it, but unfortunately they have become traffic congestion points that put pressure on even the side streets in the capital, Riyadh. This problem requires solutions, even if they are partial and temporary, until permanent solutions to this issue are reached. At the forefront of these solutions is the operation of the public transportation system in the capital, including the almost completed tunnel networks and the network of transport buses that roam the capital empty in long experiments that have become a burden on traffic instead of be part of the solution, but we are hopeful and optimistic that the tunnel and bus network will soon be launched in the capital because they are one of the radical solutions to this stifling traffic crisis.

Research methodology

To find out how riyadh citizens struggle with the daily traffic, we asked them directly. We shared a survey to several whats app work groups as well parents groups (many of whom messaged us in addition to answering the survey) We sent the survey to a group sample of workers and parents who live in Riyadh City we anonymized all of our informants. Our questions included:

What are the causes of traffic in Riyadh?

Who is responsible for this traffic?

What are the solutions in your opinion?

Why is he responsible for the traffic in Riyadh?

Our goal in approaching different types of citizens was not to get a representative sample of the whats app groups but to elicit potentially diverse perspectives. Given the issues mentioned above, we are able to assess how many people saw our survey. We received 8 responses from over 300 members users through shared messages who replied to our queries. The responses we received revealed many different perspectives on audience. While we can quantify audience perspective to the issue the responses we received provide valuable insight into some core differences in conceptualizing audience. Future empirical work might examine the prevalence of these answers and their relationship to citizens counts, demographics, or social status. As we now demonstrate the answers of our survey

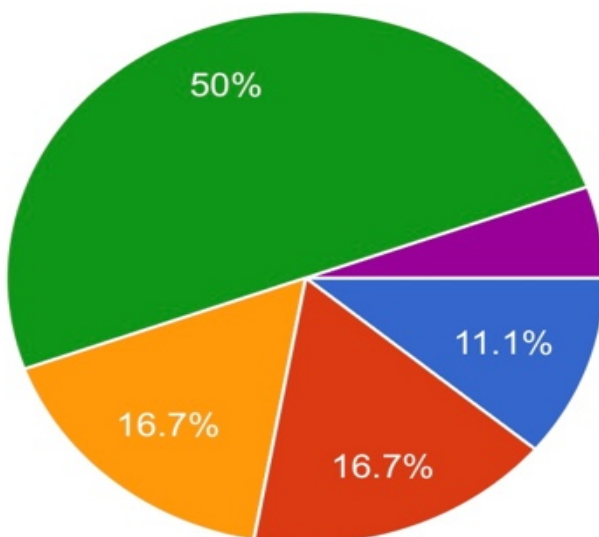
What are the causes of traffic in Riyadh?

Compatibility of working hours and overlapping of business sectors' working hours with educational institutions. Closing some streets and relying on narrow main streets and lack of paths. The presence of jobs, major companies, ministries, agencies, and entertainment and cultural events in the city of Riyadh is greater. Infrastructure. Population density and large number of cars. Many green buses, labor buses, and trucks. The large presence of foreigners, permitting visit visas, and preventing them from returning. Lack of awareness of the basics of driving and following the correct and specified route, or the legal speed of the road

What are the solutions in your opinion?

A flyover bridge like Kuwait City is being built to ease congestion. Establishing supporting roads for the main road (for example, Kharia's Road is the only road that connects the east to the west. There is no other option, so most of the time the road is crowded) and all roads are in this way. Do not move some companies outside of Riyadh or neighboring areas to revive them, move industrial cities outside of Riyadh, prevent workers. Buses avoid being present on public roads during times of congestion. There is an alternative or supporting route that relieves congestion. Returning to the "primitive" method, which is mass transportation, and instilling this culture through subsidized and free activities and performances so that the citizen can use this means. Organizing working hours for employees - students - universities and colleges. Operating trains and expanding an advanced transportation network throughout Riyadh and linking nearby cities and governorates to a high-speed train network. Establishing fast lines for buses and trucks, changing the working hours of companies, for example, in the middle of Riyadh, and his work center there works at such and such time, and the one in the north of Riyadh has such and such time, or organizing the number. Stopping visit visas, correcting residency conditions, activating flexible working hours in some sectors, allocating some days to educational institutions (remotely), and activating flexible working hours in business sectors + eliminating old cars for disrupting traffic + imposing a fine on workers and owners of trucks whose speed is less than 100. Educating the people to follow the designated lane and the legal speed of the road.

Who is responsible for the traffic?



- ① Traffic management due to its weak ability to control congestion.
- ② The culture of the population of the city of Riyadh is such that every person owns a car.
- ③ Inactivation of public transportation.
- ④ Weak planning in terms of placing all ministries and departments in one road or one area.
- ⑤ Failure to activate government electronic services to remove bottlenecks in ministries.

Why is the reason you chose in the previous question responsible for the traffic in Riyadh?

As you can see from the pie chart the option number (4) got chosen the most by 50% who agreed that Weak planning in terms of placing all ministries and departments in one road or one area because suddenly, there were projects in Riyadh and the population density increased, and the streets could not accommodate the number of cars in them. hundreds of millions have been spent on bridges, tunnels, and roads, and we see that this is a form of renaissance and modernity, such that we find the first countries in the world that do not have this large amount of asphalt, which turned the city of Riyadh into a black city consisting of cars, sidewalks, and palm trees in an ugly view, and we fought mass transportation. A country considered a continent in which there is only “SAPTCO” for mass transportation around cities!! No trains, no metro. In contrast, in the poorest countries in the world, such as Abyssinia, we find that the metro has been operating there for decades! But what I want to add is that when we think about operating the metro in the future, we must not price its ticket at a high price, as everything is more expensive than everything around us. This, and God and His Prophet know best. when planning is the most important thing to solve the problem, they do not have a major and permanent role in finding traffic solutions until after the problem occurs! This sector must be allocated to be profitable and capable of finding solutions while participating with international bodies - randomness and ministerial confusion between tourism and entertainment, attracting visas to the good and the bad, a terrible spread of violators in most neighborhoods of Riyadh, poor study and planning among them, lack of agreement with the Ministries of Interior and Foreign

Affairs - failure to develop future plans for planning. Polarization and studying the challenges in transportation - in Arabic. The ministries must meet, study the situation, and come up with a sound and plan that benefits society and benefits the economy.

Literature Review

Certain unreasonable urban transportation policies and practices can cause traffic jams, demand a lot of time and energy, reduce the effectiveness of commuting, and increase weariness, tension, and anxiety. Additionally, heavy carbon dioxide emissions from motor vehicles and a packed and congested transportation planning environment may have a negative impact on commuter comfort.

2.1. Traffic index

Traffic jams lengthen travel times, make arrival times unpredictable, and lengthen car lines. It has also been discovered that traffic intersections are detrimental to society.

2.2. Time index (in minutes)

People's daily time budgets are greatly reduced by commuting, which means they have less time for other, more enjoyable pursuits. The last time someone traveled, the longer they were away from home, must commit to other activities, which raises stress levels, deteriorates mental health, and has a negative effect on job satisfaction.

On the other hand, reduced travel times can promote more time spent sleeping and exercising, both of which are beneficial to one's physical and mental well-being.

2.3 Time Exposure Index

Traffic commute times are thought to be a significant factor in an individual's quality of life, and more productive commutes will benefit travelers overall. Thus, in order to make commute time efficient, pleasant, and of high quality, urban design must take into account a plethora of amenities like sidewalks, bike lanes, and safe and comfortable bikes. Convenient public transit can also be a relief to those who make frequent, active excursions. To put it another way, meaningful travel makes time spent traveling more valuable, which could lead to people feeling as though their journey is passing more quickly without actually cutting into their travel time.

2.4. The index of inefficiency

Inefficient transportation not only costs cities money, but it also pollutes the environment. Enhancing public transportation, providing better service, and promoting non-motorized mobility can all help to increase or print transportation efficiency.

2.5. Index of CO2 Emissions

Even in medium-sized cities, there is an increase in pollution due to traffic-related greenhouse gas emissions, such as CO₂. As a result, numerous research are examining vehicle emissions in an attempt to find ways to reduce pollution.

Conclusion

The study's findings emphasize the significance of urban transportation, planning, and enhancing population well-being through the optimization of transportation infrastructure. People spend less time on daily travel when the transit commuting time index decreases, which frees up more time for leisure and family activities and may enhance people's quality of life. A more effective transportation system could lessen people's everyday stress and improve their quality of life.

Vehicle technology is not the only solution for achieving sustainability in the transport energy sector. Instead, it is worth exploring the effects of potential policies to stimulate behavioral changes. One such avenue may be policies that shift a substantial amount of travel to public transit. Many policies are advocating for such a shift in response to the transport sector's environmental impacts and energy demand. Understanding modal shift scenarios requires information on travel behavior and other specific factors that are available for the Riyadh metro.

Reductions in energy use and carbon dioxide emissions through the modal shift to public transit depend on train and bus occupancy rates, which can vary significantly. Potter (2007) observes that buses and trains offer 1.5 to 4 times greater energy efficiency than cars in terms of seat kilometers. However, their energy efficiency is only zero to two times greater when their current occupancy is considered. These results also vary according to trip purpose. For example, in the case of commuting, car occupancy is lower and public transport occupancy is very high. Thus, the average car commute uses over five times as much energy as the average public transport commute (Potter 2003). However, the gap is narrower when all trip purposes are considered.

We may assume that shifts to public transport increase vehicle occupancy and thus improve fuel efficiency per passenger kilometer. Furthermore, we assume that the modal shift approach can reduce the demand for private car mobility. This demand reduction is driven by a combination of better urban planning, improved infrastructure and better public transit systems. In addition, effective policy measures can encourage the use of public transit modes, such as the metro and BRT. In practice, modal shift patterns are constrained by various factors, such as people's willingness to change their behavior and government policies. Constraints on the levels of investment and costs of using the respective modes also impact the modal shift patterns.

Modal shift patterns are also strongly associated with the pattern of land use in a city. To reduce passenger kilometers by private cars, land use and public transit must be well integrated. Efficiently integrating the two can be complex, and it is not always clear how to optimize one mode over another. Changing land-use patterns can directly affect transport systems and vice versa, and thus can affect modal shifts. For instance, metro development can lead to much denser land use patterns around stations, which can drive travelers to shift from cars to the metro. Cuenot, Fulton, and Staub (2012) indicate that managing land use in an area can reduce the number of trips elsewhere by up to 30%. They show that imaginative parking policies can achieve at least a 10% shift away from private vehicles. They find that BRT systems can shift at least 5% of trips from cars to mass transit. Finally, they explain that the modal shift of car and taxi users to BRT in cities implementing this system is between 6% and 21%. The estimated models provide some direction for determining the impacts of such shifts in travel patterns.

Older travelers prefer to keep using their current mode, whereas younger car and taxi users intend to switch to the metro. Travelers with higher education levels are likely to change their current modes to the metro. The reason for this result may be that well-educated people prefer environmentally friendly transport options such as the metro. Moreover, the switch from car to metro travel for work trips is likely associated with educational attainment. Shopping, personal business, and social and recreational trips are less likely to shift to the metro than work trips. This may be because serious traffic congestion can add more uncertainty to work trips. Metro services may be more reliable than driving. Overall, people who are employed, single, traveling for work, and are more educated are more likely to choose the metro. By contrast, people who are less educated, unemployed, part of a nuclear or extended family or travel for non-work reasons are more likely to maintain their current transport mode. Furthermore, the models show that the new metro can significantly lead travelers to change their mode choice. The proportions of taxi and car users that shift to the proposed new metro service may reach 51% and 23%, respectively. This may be because the new Riyadh metro is committed to providing reliable, efficient and affordable public transport for Saudi residents. Additionally, metro cars and stations will be under continuous advanced surveillance and will be equipped with the latest technological advancements to ensure user safety. These study findings are useful for metro planning in Asian cities such as Riyadh, where private vehicles generate the majority of trips.

The results show that the metro has a high potential to attract users of private vehicles, such as cars and taxis. Adequately improving the metro's service level and introducing road pricing, including parking fees for high importance zones, such as shopping malls, are highly likely to enable a modal shift to the metro. The metro system should be planned to significantly decrease travel times and be affordable to limit the use of private vehicles. Finally, this study provides explicit knowledge on and facilitates an understanding of travelers' perceptions of the metro service, including factors that impact their chosen modes of transportation. This information can lead to sustainable transport development in Riyadh. Moreover, strong measures can be adopted on short- and long-term bases and progressively strengthened over time. In this case, a much greater modal shift can be achieved, thereby creating energy efficiency gains.

Finally, our results are based on a survey conducted in 2013, when women were not allowed to drive in Saudi Arabia. Since June 2018, women have been allowed to drive in the Kingdom. Consequently, about 81% of women in the country have expressed their intention to obtain a driving license, and among them, about 36% wanted a license immediately after the ban was lifted. Approximately 76% of women intended to drive after the ban was eased (Al-Qarawi et al. 2018). Riyadh Province has the highest proportion of women who intend to drive. Therefore, easing the ban has undoubtedly added to car travel, which might have caused increased travel times/congestion, as well as higher emissions. This additional scenario could not be reflected in this analysis because the survey the analysis is based on was conducted before 2018.

Furthermore, Saudi Arabia has adjusted gasoline prices on a quarterly basis since early 2019, and this adjustment would also bring some changes in the modal choice of private car travelers.

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