Sustainable Transportation in Qatar

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***Abstract*—Qatar has initiated a vast megaproject including an integrated transportation service. To meet the need for ongoing demand, the Government of the country instigated the bus and taxi service under the KARWA banner. The study aims to evince the sustainability of the KARWA service. In terms of acceptance, it is evident that those different modes of transportation have two different scenarios. Therefore, the study evaluated the sustainability of bus which is comparatively lower acceptance in terms of public acceptance. It is observed that public acceptance could be regulated following different aspects such as time reliability, safety, comfort, and privacy, etc. On the other hand, the taxi service is evaluated following the technological aspect. For KARWA Taxi, three-car technologies have been compared, which were Conventional Internal Combustion Engine, Electric, and Hybrid Cars. It has been found that Hybrid Taxis have better performance in terms of cost, emission reduction, mobility, and traffic noise compared to conventional cars. Finally, for those two modes, the application of smart technology is evaluated, and it is inferred that the utilization of the tools in a sufficient manner can make those transportation more sustainable.**

Keywords-sustainable transportation; bus; public acceptance; electric cars; hybrid taxi; smart applications

I. INTRODUCTION

Qatar – one of the smallest countries in the world- is considered as an emerging regional powerhouse of the countries of the Arabian Peninsula. Despite its small land area, it has vast gas and oil reserve and related economic growth, and the enrichment in the natural reservoir has increased the number of populations of the region significantly the country had a population below 30,000 prior to the discovery of oil, which accelerated dramatically due to increased oil revenues after 1971 [1].

In an affluent city, the travel behavior of the inhabitants is private car orientated and Qatar is a splendid example of this being one of the largest per capita vehicle owners in the Middle East region. Most of the people are private car-dependent, and with the growing population, the number of private cars is increasing significantly. This dependency on cars can result in the immethodical use of non-recyclable energy, the creation of pollutants and greenhouse gases, noise pollution, and cities with a high volume of private vehicles. The dependency on private vehicles have greater traffic, yet when policymakers and urban developers ignore this issue and fail to find a solution to manage the traffic. Therefore, integrating such enormous mega-development with the increased population by providing sustainable transportation has become a challenge for Qatar.

Qatar's vision of 2030 includes different social and environmental improvement of the region and providing a safer and sustainable transport system with an efficient and smooth movement is one of them. One example is Qatar's road safety strategy 2013–2022, which has reduced the number of fatal crashes during the last five years. On the other side, sustainable transportation refers to a transportation mode with less environmental impact by consuming less energy, provide a safer movement with convenient access to destinations, and most importantly widely accepted by the consumer [2-12]. Therefore, the Government instigated different projects such as metro, rail, bus, and taxi service through an extensive strategic plan. Some of them such as rail and metro are in the development phase whereas two modes of transportation such as bus and taxi service under the banner KARWA have already been implemented.

In this study, for KARWA bus service, the feedback from the non-consumers of the bus service in Qatar is evaluated in Section I to categorize the factors that regulate the choice, and then provide benefits and solutions to implement for the concerned authorities. Regarding KARWA taxi, hybrid vehicles are more sustainable than gasoline ones, details of which are presented in Section II. Finally, the use of smart applications for transportation will also increase public reliance and attract them towards public transportation due to their ease of use which is covered in Section III. In the end, all this work is summarized to draw the conclusion.

II. KARWA BUS

A major improvement to the bus system was carried out during the Asian Games 2006 in Qatar. The use of buses as an official transportation mode for this event eventually increased the afterward use of this public transportation. In 2007, Mowasalat introduced the main plan for the bus service and now it is providing day-long bus service along 51 routes within Doha buses are scheduled every 15 minutes between stations [13-14].

The bus is implemented with a view to providing sustainable public transportation. In addition to lowering the carbon emissions from transport, sustainable transportation has different aspects such as environmental, social, and economic. In the social aspect, the public acceptance of specific transportation is considered [15]. The most efficient public transportation system could not provide a level of service up to the mark for another region. Therefore Singapore, Tokyo, and Hong Kong with their most adaptable facilities for their own cases, are not representative around the world [16]. A similar conclusion is also made in Europe and Brazil [17].

Transportation that does not provide the service to the consumer up to the mark or not accepted widely can't be considered as sustainable [18]. It is observed that after a decade of bus implementation, the number of bus users is very low, and the current state of bus transport is acceptable to low-income people only. But, for an integrated sustainable transportation system by incorporating the current bus service and the prospective Doha Metro, train, etc., it is important to find out how this ridership on a bus can be increased to have acceptance by the public on large scale [19-23]. Therefore, it requires the need of evaluating the factors that regulate the choice of a consumer to choose a bus for daily movement.

The consumer can be categorized into two different aspects such as user and non-user. A study evinced the current user satisfaction in Qatar regarding the KARWA bus by evaluating the different levels of services [13]. It concluded that the use of the bus is limited to people who are male, middle-aged people, foreigners, residents, low-income employers and do not possess private vehicles. It also indicated that students are not susceptible to use bus service. However, the study could not have inferred regarding the non-users' interpretation regarding the current bus service. Therefore, in this study, the non-users outlook towards the current bus system is evaluated.

A. Non-consumers Feedback for Bus Service in Qatar

In this study, a total number of 100 questionnaires are distributed among the non-user people in several locations in Qatar University. During the process, the questionaries with at least 80 percent response were considered for evaluation. Respondents were asked to provide different personal information (gender, possession of driving license), as well as the different levels of services of current bus services (time reliability, safety, cost, comfort, privacy, frequency, required walking distance to bus stoppage). The respondent was further asked about the possibility of using a bus service with an induced situation. In the induced condition the bus service is expected with higher reliability, safety, and equal comfort and privacy to the private vehicle. It is also considered that bus service is frequent, and passengers can track the bus service through the mobile app. The statistical test, Analysis of Variances (ANOVA), has been performed to evaluate the influence of the mentioned factor on the choosing bus. Statistical observation of the data was carried out based on null (denoted by H0) and the alternative hypothesis (denoted by Ha). The null hypothesis is rejected in favor of the alternative hypothesis if the P-value is less than or equal to a significant level (α). A significant level of $\alpha = 0.05$ was used in this study. Table I shows the evaluation results.

TABLE I. ANALYSIS OF VARIANCE

Factor	Time	Safety	Comfort	Privacy	Frequency
P-value	0.046	0.000	0.016	0.029	0.375
Decision	Significant				Insignificant

It is observed that the choice of bus service is regulated by the time reliability, safety, comfort, and privacy, whereas the frequency was found as insignificant. Therefore, those outcome dictates the necessity of evaluating each significant factor individually. Further evaluation using Fisher's comparison method evinced that the induced situation makes the respondent interested to use the bus. Therefore, improving the observed significant factor could results in an increment in the bus user.

The respondent was also asked to rank the current level of service of some other factors such as cost, required walking distance for bus stoppage, and based on it they were further asked about their expected level of service. It is observed that 48% of total respondents ranked the cost as good, whereas 32% ranked it as average. It is also observed that 56% of total respondents ranked the currently required walking distance as bad and 9% of total respondents ranked it as good, only. In further evaluation, it was observed that 42% of respondents expect a walking distance within 5 minutes whereas 37% of respondents expect a walking distance within 5 to 10 minutes.

B. Factors of Low Ridership on KARWA Bus Service

Based on the previous, and the current evaluation it is observed that there are several factors that regulate people's choice of the bus in Qatar. Based on the survey following the perception of the user and non-user of the bus, the following thing can be evinced:

- KARWA bus stop stations are limited.
- The bus has punctuality issues.
- Traveling time-based on the destination is not reliable.
- The bus is crowded during peak hours.
- Stations lack basic facilities like shade, water, etc.
- Nationals, women, children, and students do not use the service and have a reservation to do so.

C. Challenges

To build a comprehensive transportation network for bus service in Qatar will be a great challenge due to the lack of coordination and integration between different regulatory bodies and policymakers. Implementation mechanisms of transport planning often found incoherent with urban planning limiting the scope of further improvements. Lack of cohesion or ability to implement programs of plan results in a gap of synchronization and coordination among different concerned stakeholders to implement policies related to public transportation. Hot weather is one of the strong factors that deters many people from walking. It leads people choosing private car or door to door taxi services during the summer. Another challenge in this zone is people's reluctance towards public transportation from a conservative religious perspective. Uncertainty lies in accepting a new mode of transport especially public transport in this region.

D. Way to Overcome

Policymakers need to develop the regulatory, institutional, and financial framework through the development of some practical strategy for an efficient private sector and providing suitable incentives for private participation to develop transport infrastructure and services. To overcome cultural nuances to accept bus and its 'sharing' effective strategies and well organized public campaign need to be adopted to persuade people to shift from car to bus. Special bus services for women back and forth to workplaces, encouraging the parents to use school buses for their children will help reduce car dependency. In addition to this, there is a social mindset that needs to be addressed to have public acceptance of Qatar bus. Awareness campaigns through radio, television, newspapers, and social media will add a valuable contribution to increasing ridership and public acceptance for these modes of transportation.

III. KARWA TAXI

The increase in Greenhouse Gas (GHG) emissions leads to climate change and global warming. Qatar Tarsheed plan was developed in line with the Qatar National Strategy 2030 to reduce CO_2 emissions. The Green Car Initiative, launched by Kahrama, aims to increase the percentage of Electric & Hybrid Cars to 10% of the total cars by 2030 [24]. The advantages of Electric Vehicles include reduced emissions and higher efficiency. The electric motor can reach up to 85-95% efficiency, compared to 28-30% for the Internal Combustion Engine (ICE) vehicles [25].

The transportation system in Qatar is currently dominated by ICE which relies on fossil fuels. Relying on power electrification is becoming more popular as a way to replace the conventional ICE vehicles. In this study, three types of cars will be considered:

1. Conventional ICE Cars.
2. Battery Electric Vehicles (BEV): Has an electric motor powered with a large electric battery
3. Hybrid Vehicles (HEV): Has an ICE along with an electric motor powered with a small battery [25].

Electric and Hybrid cars will be compared to ICE cars in terms of cost, emissions, mobility, and traffic noise. Based on the results, a plan will be proposed for KARWA taxis to promote sustainable, yet practical technology.

A. Economic and Environmental Comparison

1) Cost

Electric cars have the highest capital cost followed by Hybrids and ICEs. The high capital cost of the BEV is a result of its large electric battery. HEVs have a small battery to operate the electric motor, therefore they are cheaper than BEVs. However, Electric and Hybrid cars are more efficient and have less running costs [25]. Electricity price is generally cheaper and more stable than petrol, therefore it is cheaper to operate electric cars compared to hybrids and ICE cars. On the other hand, hybrids have a better fuel economy (30-34%) compared to ICE cars, which reduces fuel consumption and operating cost. In the next section, the different Life Cycle Assessment (LCA) studies are reviewed to identify the payback period of the high initial cost for electric and hybrid cars.

In a study, electric, hybrid, and ICE cars were compared in terms of economic performance [25]. The life cycle is 10 years, assuming an annual distance of 15,000 km for a total distance of 150,000 km. Table II summarizes the capital cost of each vehicle and the total cost after 5 and 10 years.

The total cost includes the capital cost plus the maintenance, repair, and fuel cost for the specified period. The results of this study show that the total cost of hybrid cars after 10 years is cheaper than the total cost of ICE after the same period. This shows that hybrid cars have a payback period of 10 years. However, the total cost of electric cars after 10 years is still more expensive than ICE. Therefore,

electric cars need more than 10 years to compensate for their initial capital cost.

TABLE II. ECONOMIC COMPARISON FOR STUDY 1

Item		Type of Car		
		Gasoline	***HEV***	***BEV***
Capital Cost (€)		20,300	25,000	35,000
Deductions (€)		-	-	5,000
Total Cost (€)	5 Years	30,161	32,059	38,841
	10 Years	41,318	40,046	43,189

2) Emissions

Electric and Hybrid cars have reduced CO_2 emissions compared to conventional ICE cars. Electric cars have zero tailpipes (road) emissions. Since they are charged by the electric grid, it is important to include the emissions resulting from electricity generation. In general, Hybrid car emissions don't depend on electricity generation. Hybrid cars are more fuel-efficient and they can reduce emissions by around 30% compared to ICE cars [25].

In the study mentioned above, the emissions of electric, hybrid, and ICE cars were compared under three electricity generation scenarios: European Union (EU), Portugal, and France. During the time of the study, the EU electricity mix is generated with 19% renewable sources, while Portugal's electricity is produced with 35-40% renewable sources. France relies on nuclear power which has very low CO_2 emissions. The emissions of Hybrid, electric, and ICE cars are summarized in Table III.

TABLE III. EMISSIONS COMPARISON FOR STUDY 1

Electricity Mix	Emissions (MT CO_2/Year)			% Reduction Compared to ICE	
	Gasoline	***HEV***	***BEV***	***HEV***	***BEV***
EU (378 gCO_2/kWh)	2.58	1.8	1.02	30.23 %	60.5 %
Portugal (365 gCO_2/kWh)	2.58	1.8	0.98	30.23 %	62.0 %
France (78 gCO_2/kWh)	2.58	1.8	0.21	30.23 %	91.9 %

The results show that the emissions of electric cars are reduced significantly when electricity is generated with lower CO_2 emissions. The use of electric cars in the EU can reduce CO_2 emissions by 60.5% compared to ICE cars, while the reduction can go up to 91.9% in France. Hybrid cars can reduce emissions by 30.23% compared to ICE cars. The percentage reduction for hybrids is similar regardless of the generation scenario.

Qatar relies on natural gas for electricity production. In study 2 [28], the emissions of electric, hybrid, and ICE cars were compared under three electricity generation scenarios:

1. Case 1: 100% Renewable,
2. Case 2: 50% Renewable + 50% Natural Gas with 40% efficiency
3. Case 3: 100% Natural Gas with 40% efficiency.

The emissions for Hybrid, electric, and ICE cars in each case are tabulated in Table IV below:

TABLE IV. EMISSIONS COMPARISON FOR STUDY 2

Electricity Generation Scenario	GHG Emissions (kg per 100 km)			% Reduction Compared to ICE	
	Gasoline	***HEV***	***BEV***	***HEV***	***BEV***
100% Renewable	21.4	13.3	2.3	37.85 %	89.21 %
50% Renewable	21.4	13.3	7.2	37.85 %	66.45 %
100% Natural Gas	21.4	13.3	12.0	37.85 %	43.93 %

Similar to the previous study, the emissions of electric cars are reduced significantly when electricity is generated with 100% renewable energy. The percentage reduction in GHG emissions compared to ICE cars is 89.21% when 100% of renewable sources are used to generate electricity. When electricity is generated using 100% natural gas the percentage reduction is 43.93%. This is 6.08% greater than hybrid cars which have a percentage reduction of 37.85%. Qatar currently has a very small portion of electricity produced by renewable sources and relies heavily on natural gas. Therefore, it is recommended for Qatar to increase the percentage of renewable sources in its electricity production to reduce the carbon footprint.

B. Using Hybrid Cars in KARWA Taxi

It has been observed that HEVs can compensate for the initial capital cost compared to ICE in around 10 years (150,000 km) [28]. Also, it was found that emissions can be reduced by 30%. It can be noticed that HEVs compensate for the cost based on the total distance covered. The more the distance the better the economic advantages. Dubai taxis were found to cover a total distance of up to 678,000 km during their lifetime [29]. Therefore, using Hybrid cars as taxis can significantly reduce the payback period. Hybrid cars have several advantages to be used as taxis. The fuel efficiency of hybrid cars can result in economic advantages over ICE as well as reduced emissions. Hybrid cars have an extended range compared to ICE cars as the battery extends the range of the ICE engine. In addition, hybrid cars are fueled with gasoline making them practical to be used as taxis. Finally, Hybrid cars can reduce traffic noise in congested areas as discussed earlier.

In a study, the LCA was performed to assess the economic and environmental impact of using Hybrid taxis in Dubai [26]. The life cycle was chosen to be three years for a total distance of 678,000 km. and the average distance covered by a Dubai taxi was estimated to be 226,000 km annually. The sustainability report for Dubai Government 2016 stated that hybrid taxis have a 34% increase in fuel

efficiency and a 30% reduction in CO_2 emissions. Moreover, a total of 1,440,242 liters of gasoline were saved and a total of 3,442 tCO_2 were reduced in 2016. After the HEV taxis were piloted for 3 years in 2013, the Dubai Government aims to have 50% of its taxi fleet as Hybrid taxis as mentioned in the same report [27].

Given the economic and environmental advantages of using hybrid taxis in Dubai, it would be advantageous to use hybrid cars in KARWA taxis in Qatar. The price of gasoline was 1.7 QAR/Liter when the study [26] was carried out. Currently, the price of gasoline is 1.9 QAR for 91-premium and 2 QAR for 95-premium gasoline. The increase in gasoline prices increases the economic advantages for hybrid vehicles as they are more fuel-efficient. It is recommended to include more Hybrid cars in KARWA taxi for the following reasons: they have reduced CO_2 and GHG emissions in urban areas, better fuel economy, excellent mobility and they can also contribute to the reduction of traffic noise, especially in congested areas.

The main challenge would be the reluctance to adopt new technology by the taxi company. There are viable solutions to overcome this issue. First, a car registration procedure could be facilitated for hybrid cars to encourage their adoption. Second, it is recommended to follow a small and gradual adoption of Hybrid taxis to allow the business to adapt to modern technology. Currently, the KARWA taxi fleet consists of 3,000 taxis. Fig. 1 shows a proposed plan for the adoption of Hybrid Taxis for KARWA.

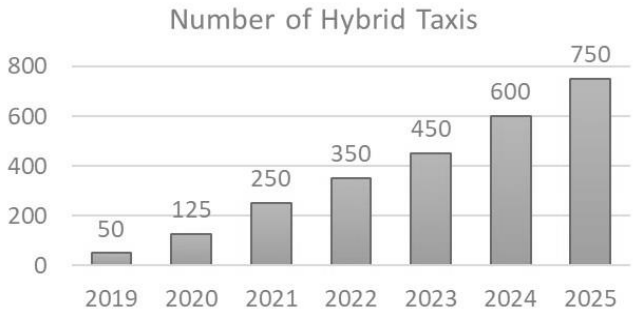

Figure 1. Proposed Plan for KARWA Hybrid Taxis.

Third, the life cycle of taxis is relatively short (3-6) years. Therefore, there is no need to convert a portion of the current fleet into Hybrids. Instead, it is more cost-effective to introduce new Hybrid taxis as a replacement to the ones which are planned to go out of service. Fourth, Hybrid cars are being commercially produced by one of the main KARWA Taxi manufacturers, Toyota. KARWA taxi fleet has many Toyota Camry brand which has an equivalent Toyota Camry Hybrid. Therefore, it would be more practical to introduce Toyota Camry Hybrids in replacement of the conventional Toyota Camry Cars.

IV. Smart Applications

The integration of computers in vehicles has bought different functionalities in the transportation system [29]. Smart mobile applications are designed using specific software to operate smartphones. There is a huge revolution in smart technologies and always keeps changing from time to time until it comes to be a primary tool that we use on the daily basis and available with many people as a communication tool.

The study focused on the changes and trials of using these electronic applications in sustainable transport. From the environmental point side, some applications can estimate the fuel emissions and consumption per type of fuel used. There are several advantages of utilizing these applications in refining and planning road traffic operations. Furthermore, it should enhance the safety culture of transportation to achieve sustainability. This research illustrated different categories of applications into different areas related insistently to the transportation sector. Furthermore, a few challenges and opportunities for improvement were found related to 1) Decision making, 2) Area of research and 3) General awareness program [27].

Absolutely, momentous usage of these applications can be possibly helpful and adding more benefits to the end-users, predominantly in the vehicle traveling time, estimating the cost, emissions, and ensure safer and living environments greener and healthier. Smartphone applications provide many benefits to various levels of users. Most of them are without cost charging. Furthermore, it is reducing driving duration, expense, risks, and impact of traffic jams, and transportation emissions to the atmosphere. Transportation agencies could gain benefits by utilizing the tools in a sufficient manner after conducting an engineering efficiency study and consumer satisfaction survey with the public in Qatar.

V. Conclusion & Recommendation

To meet the need for present and future demand, the Government of Qatar instigated the bus and taxi service under the KARWA banner. The study aims to evince the sustainability of the KARWA service. Here, the sustainability of the current KARWA bus and taxi service in Qatar is evaluated following two different approaches. The sustainability of bus service is evaluated based on public acceptance whereas the taxi service is evaluated following the technology. Based on the evaluation it is inferred that there are many reasons behind the less acceptance among which insufficient supply to demand, unattractive stoppage, time reliability, longer waiting time, convenience, privacy, and safety, etc. In addition to improving those factors, an integrated approach for the current bus system is needed following the local need. It has also been observed that Electric and Hybrid cars can reduce traffic noise and CO_2 emissions compared to ICE cars. Qatar with increased electricity production from renewable sources can maximize the environmental advantages for prospective electric cars. Moreover, the adoption of hybrid taxis could lead to having economic and environmental advantages compared to ICE cars. To evaluate the potential of using the hybrid taxis in the KARWA taxi fleet, a comprehensive study is recommended. Moreover, transportation agencies could gain the benefits of smart applications by utilizing the tools in enough manner

following the evaluation of efficiency and consumer satisfaction in Qatar.

It is also recommended to furtherly investigate the accuracy of these applications for traveling information collection and the opportunity for sustainability, understand the effect of the smart applications in improving the reliability of sustainable transportation, and increase the road user awareness education on public transportation especially on the consequences risks while operating the vehicle in unsafe conditions.

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