Towards Enhancing Sustainability: A Novel Approach for Reducing Carbon Emission During the Transportation of Zamzam Water by Pilgrims during Hajj and Umrah

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Abstract

Millions of people visit Makkah for *Hajj* and *Umrah* as part of Muslims religious activities. One of the gifts people take home with them to friends and family is the holy water of Zamzam. Currently, water is packaged in 5-Litre special containers to be transported for that purpose. Most pilgrims use air transportation and carry with them Zamzam water gift. This paper explores the carbon emission currently produced by airlines by this excess weight and the possibility of reducing carbon emission by replacing the air transportation of water by other means using land and sea alternatives. This paper has focused on main cities and airports of the world where pilgrims travel from and to. The results indicate that more than 81 thousand tonnes of CO2 could be saved annually with an estimated reduction of more than 96% tonnes of CO2.

1. Introduction

Hajj is the annual pilgrimage to Makkah in Saudi Arabia where Muslims are expected to make at least once in their lifetime. It could be described as the biggest annual movement of people on Earth. Umrah is the visit or pilgrimage to Makkah during non-Hajj times. Figure 1 presents the Grand Mosque in Makkah during the busy times of Hajj. According to the Saudi General Authority of Statistics (GASTAT, 2019) about 2.3 million pilgrims have visited Makkah in 2018 and among them there are about 1.7 million foreign visitors. During Hajj and Umrah all those millions of visitors drink from and use Zamzam water. Zamzam water has a special place in Hajj and Umrah for Muslims. According to BBC (2009), Muslims believe that Prophet Abraham brought his wife Hajira and their son Ismail from Palestine to the uninhabited and dry valley of Makkah (Mecca) in Arabia as he was instructed. Hajira, in this area of dry land ran up and down two hills named Safa and Marwa trying to look for water and seek help. When she failed, Ismail struck his foot on the ground and this caused a spring of water, namely Zamzam, to stream under his feet. By securing this water supply, Hajira and Ismael were able to trade water with passing travellers for food and supplies (BBC, 2009). This religious and cultural importance of Zamzam water is still continuing in the 21st century. To meet the demands of pilgrims, King Abdullah ibn Abdul-Aziz Project for Zamzam Water factory transports 5 litres water containers to Jeddah Airport (King Abdulaziz International Airport in Jeddah - KAIA) and Madinah Airport (Prince Mohammed bin Abdulaziz International Airport in Madinah - PMIA) (NWC, 2019). About 11 million containers were distributed to pilgrims in 2018 from the two airports only. According to GASTAT (2018), more than 19 million people performed Umrah in 2017 (19,079,306 pilgrims), about 88.29% used air travel while only 4.56% used other modes of transportation.

Figure 1: Hajj activities in the Grand Mosque of Makkah (Mecca) in Saudi Arabia.

As seen in Table 1, among foreign pilgrims, 94% travelled by air (1.65 million pilgrims in 2018) based on ASTAT (2019). In addition to Hajj activities, Umrah activities, which is the visit to the Makkah during times other than the Hajj, also has a similar nature of transporting Zamzam water, where 92.9% of Umrah pilgrims travelled by air (6.2 million) based on GASTAT (2018). This means if every pilgrim carries with him or her at least one standard 5 Litre Zamzam water container, the result is about 39 thousand tonnes of additional weight to fly back with them to their own home countries. This will lead to massive carbon emission as all this weight is being transported currently by air.

Table 1: Statistics of foreign Pilgrims for Hajj 2018 (1439H) and Umrah 2018 (GASTAT, 2019 and GASTAT, 2018 respectively)

Mode of transportation	**pilgrims (Hajj)**		**pilgrims (Umrah)**	
Mode of transportation	**Ratio**	**Number of pilgrims (Hajj)**	**Ratio**	**Number of pilgrims (Umrah)**
Air	94%	1,656,936	92.9%	6, 285,931
Land	5%	85,623	5.8%	397,818
Sea	1%	16,163	1.2%	81,863
Sub total		**1,758,722**		**6,765,614**
Total		**8,524,336**		

According to Cefic and ECTA (2012), Carbon emission levels for different modes of transportation can be summarised in Figure 2, where aeroplanes are the highest carbon emitting mode of transportation with about 602 grammes per tonnes transported per km. The road, rail and sea have an emission of 62, 22, 8 grammes respectively.

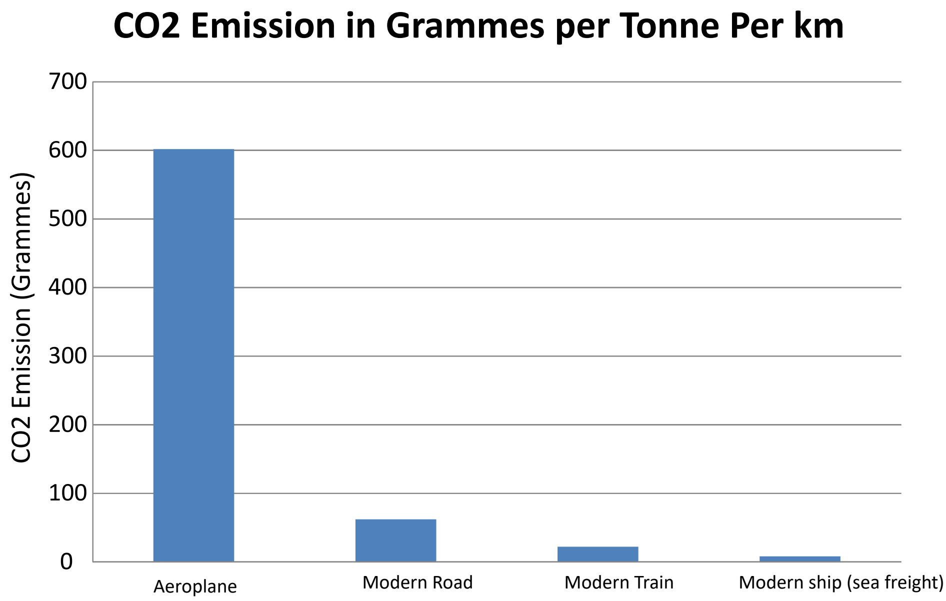

Figure 2: CO2 Emission per mode transportation per tonnes per km travelled

The authors in this paper explore the approach of transporting Zamzam water by different modes of transportation, i.e. sea and land, and the potential carbon savings per annum within the current figures of pilgrims. This should allow more profit to airlines and at the same time help reduce carbon emissions.

2. Transportation solutions to decrease pollution and reduce global warming

One of the major contributing factors to global warming is transportation. Studies have shown that transportation accounts for approximately 20% of the world total CO_2 emission caused by the burning of fossil fuels (IEA, 2014). Pollution and carbon emission could be related to mode of transportation or the routing of the transportation process. According to Nasab and Lotfalian (2017), transportation routing problem for vehicles uses optimisation and integer programming to discover the best routes for fleets of vehicles. This optimal set of routes, particularly with complex network of routes and transportation problems, plays an important role in reducing fossil fuel consumption, thereby, reducing CO2 emissions (Zhang et al., 2015). According to Bauer et al. (2010), fuel and vehicle usage costs that are incorporated into the conventional routing problem have established a lower-carbon routing solutions. Fagerholt et al. (2010) have proposed a model which can be used to reduce fuel consumption and fuel emissions through the optimisation of speed of driving. A mathematical model formulated by Nasab and Lotfalian (2017) has been implemented to reduce carbon emission and fuel consumption by delivery trucks through defining a classification method of the routes taken by those vehicles based on average speed and then minimising the delivery time and operational cost. In their model, the level of pollution during transportation is considered a penalty for the optimisation of the algorithm. Their results have indicated that when comprehensive fuel consumption factors are considered in an optimisation model, the pollution to the environment and carbon emission can be controlled through enhanced route planning.

According to The Financial Times (2016), one of the world's largest studies has shown a strong relationship between long-term combined exposure to air pollution and traffic noise on blood pressure. Therefore, the mode of transportation is found to be a significant factor in reducing pollution and carbon emission and hence improving public health on the long term.

It has been argued that sea transportation could provide significant reductions in air pollution and promote cleaner transportation. This is because water transport systems have large capacity and offers lower fuel consumption and cost per kilogram. Hence this mode of transportation has been characterised as being green (Spielmann and Scholz, 2005). For transportation between coastal cities, an effective way of achieving reduction in carbon emission is by promoting the use of sea transport. For example, in 2016 the Chinese government has proposed a policy to promote the development of an integrated transport system in coastal areas with emphasis on sea transport (The State Council Information Office of the People's Republic of China, 2016). In the UK, The Government Office for Science (2019) has stated that "Our reliance on automobiles extends to the freight sector; by tonne-km, 76% of freight goes by road, compared with 15% by water and 9% by rail". The future policy was targeted towards "Consider transport as a system, rather than loosely connected modes". The European Union has proposed "the motorways of the sea program", which is a strategy that encourages transportation systems to increase the usage of water and sea transport systems (Douet and Cappuccilli, 2011). The United States has also proposed "the marine highway program" in order to enhance the utilisation of sea and water transport (Chen et al., 2014). Previous transportation research work in literature was mainly focused on the road transportation, as air and sea cargo routing is much simpler and more flexible to address. Matas and Raymond (2003) have analysed the traffic demand on tolled roads with respect to different variables that would influence travel. Other researchers have looked at policy issues and costing; for example, Armelius (2005) has analysed an integrated urban road pricing policy based on an automatic payment system for cars. Potter and Parkhurst (2005) have conducted studies on measures of tax and subsidies that the British government could implement for road transport systems to address the problem of carbon emission and pollution.

Many studies have been done to address the environmental issues in recent years using mathematical modelling and programming techniques. For instance, De et al. (2018) have proposed a linear programming model to study the port berth management where fuel cost is linked with the operational time of a docked vessel. Gu et al. (2019) proposed an optimisation model to integrate fleet operation with the application of the levels of pollution emission. Lee et al. (2013) have analysed how carbon tax on container-shipping systems can affect global trading and emission levels. The results of their study have shown that carbon tax may not affect the global economy but might have an influence on China's economy. Studies by Verhoef (2002), Lawphongpanich and Hearn (2004) and Ekström et al. (2009) have looked at emission and transportation models. Several new concepts have been developed to address such problem in the past decades. Lawphongpanich and Yin (2010) have developed the concept of "Pareto improving" where the decision makers are expected to bring policies to reduce transport delays but without affecting the interest of travellers negatively. Another reference, Di et al. (2016), has introduced a biased choice factor which suggests that network or road users would prefer a specific choice when making selection of their travel routes. This human factor would influence transportation networks beyond the classic mathematical modelling. With regards to sea transport from the perspective of shippers, Lim et al.

(2008) have proposed a model suitable for procurement to assist shippers to reduce their transportation costs. Lu et al. (2017) have developed a portfolio-management solution for seasonal goods to provide an optimal transportation service plan selection model in order to maximise capacity and enhance efficiency. It is clear that the cost of freight will depend on several factors such as means of transportation, shipping distance and weight, and the shipment quantity (Macharis and Bontekoning, 2004); and hence this should be taken into consideration when planning any transportation process to optimise the overall reduce performance and reduce costs.

According to the European Environment Agency (EEA, 2013), the goal to protect the environment such as air quality should be towards an overall system's output. In an optimisation algorithms and performance analysis, it is commonly noticed that sustaining the environment depends on carbon footprint and the role played by air pollutants is often neglected. Münster et al. (2015) have carried out a study to optimise the Waste-to-Energy (WtE) handling solutions with focus on the greenhouse gas emissions (CO2, CH4, N2O) as the main environmental parameter. Carbon Emissions Pinch Analysis (Foo and Tan, 2016) and Greenhouse Emission Pinch Analysis (Kim et al., 2016) have been proposed as means of reducing negative emission. The Carbon Emissions Pinch Analysis technique has also been applied to transportation analysis (Walmsley et al., 2015); where the developed model considers parameters such as the cost, reliability, flexibility, frequency, transportation time/speed, safety, quality and environmental sustainability. Bask and Rajahonka (2017) focus on the criteria Greenhouse gases or CO2 emissions to develop the sustainability measure. However, consideration should be taken to air pollutants for a comprehensive approach to transportation.

This paper will address the problem of transporting Zamzam water from Saudi Arabia to pilgrims' home countries after performing Hajj or Umrah. Based on the above, carbon emission will be used as the criterion to assess performance. The paper will compare between the current scenario and the suggested and integrated approach for main countries and will discuss other factors that could influence the suggested scenario.

3. Methodology and Assumptions

3.1 The novel suggested Approach

Zamzam water is filled for airport travellers in standard 5L containers, where containers are taken home by pilgrims. In this paper, an assumption was made that the Hajj passengers will each carry with them only one 5L container to take home. Figure 3-a presents the current model, where the passenger will take the water container as luggage to final destination.

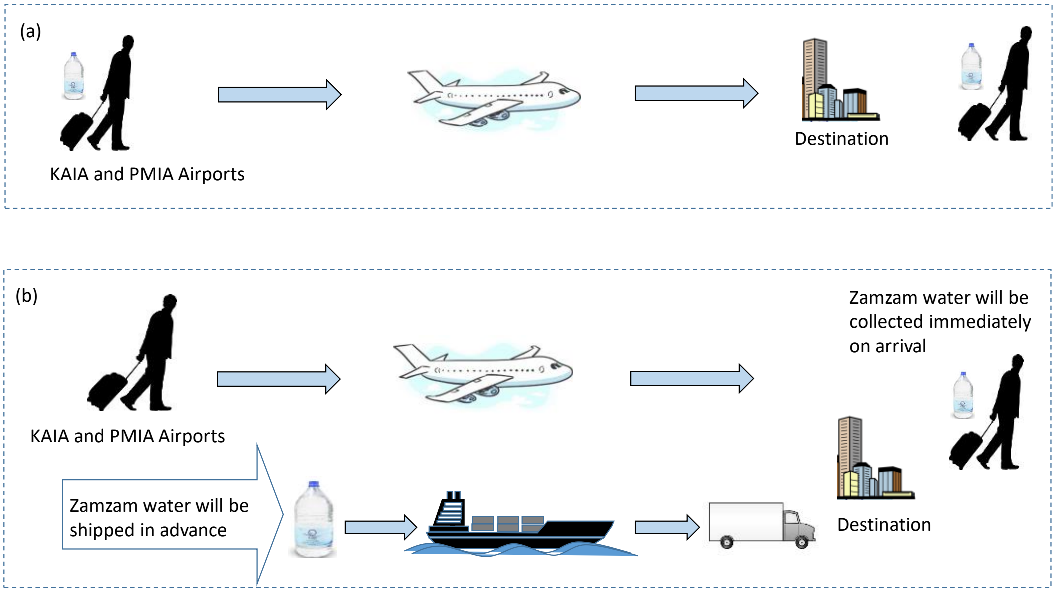

Figure 3: A comparison between the current scenario (a) and the proposed scenario (b).

The proposed system, Figure 3-b, is to ship by sea and land a quantity of Zamzam water containers well in advance of the passenger's travel using data based on issued travel visas and confirmed flight reservations. Hence, the passenger will receive a coupon from the airport of departure in Saudi Arabia to pick up a 5 Litre water container immediately upon arrival to the destination airport. In this case, the pilgrim will travel on the plane without a water container, but the final results will be the same, receiving the bottle of water upon arrival. There could be some cultural challenges from pilgrims, but this is expected to improve overtime. Looking at the Hajj and Umrah statistics, it has been found that 77% of pilgrims come from specific countries from Middle East and Far East as shown in Table 2. Based on this, the distance travelled by air for the 6,303,762 Umrah and Hajj pilgrims is calculated based on the location of King Abdulaziz International Airport in Jeddah (**KAIA**) and Prince Mohammed bin Abdulaziz International Airport in Madinah (**PMIA**) and the relevant airport in those specific countries. The 77% of pilgrims are expected to carry with them about 31.5 thousand tonnes of water.

The methodology used in this paper will include specific assumptions, and based on that, alternative sea and road routes will be calculated to estimate carbon emission. Google Earth is utilised to estimate the coordinates of major cities and airports. Straight line flight distance calculator (Csgnetwork, 2019) is used to estimate the distances. Stevemorse.org (2011) is used to batch distance computations based on latitude and longitude. Copypastemap (2019) is used to plot the maps from excel data. A factor of 1.852 is used to convert nautical miles to km.

The main assumption is that flights will depart from and return to major airports in each of the top 10 countries of the 77% of pilgrims. The main airports in each country in the statistics where examined. If the majority of pilgrims in any country fly to a nearby city on the sea side where there is a seaport, this situation will be named best case scenario (BCS), as Zamzam water will be transported to this city directly with limited land transportation. However, if the major destination city is further in-land and needs significant road transportation, this scenario is named worst case scenario (WCS). For example, in the case of India, airports and cities of New Delhi and Mumbai are used as the main destinations for WCS and BCS respectively. This helps to compare between savings between nearby cities on the seaside and in-land cities further away. Hence BCS is also called 'Near' scenario while WCS is named 'Far' scenario.

Table 2: About 77% of pilgrims in 2018 came from mainly 10 countries

Destination	Total Hajj and Umra - KAIA	Total Hajj and Umra - PMIA	Total Hajj and Umra by Air	Cumulative	Cumulative (%)
Pakistan	1129755	672588	1802343	1802343	22
Indonesia	570208	657514	1227722	3030065	37
India	428587	343949	772536	3802601	46
Turkey	323058	307976	631034	4433635	54
Egypt	290923	186561	477484	4911119	60
Algeria	246720	196290	443010	5354129	65
Malaysia	130824	160757	291581	5645710	69
UAE	169040	97944	266984	5912694	72
Bangladesh	228264	16655	244919	6157613	75
Iraq	120654	25495	146149	6303762	77

3.2 CO2 Mathematical Modelling

Let C be the carbon emission from a transportation process (grammes). For a weight w of Zamzam water (in tonnes) for a journey consistent of N stages journey with distance d_i (km) and carbon factor k_i where i is a stage of a journey with a given distance d_i (km) and carbon factor k_i, (grammes per tonnes transported per km), the carbon emission C can be calculated as in equation (1) below.

$$C_{i \to N} = w \sum_{i=1}^{N} k_i d_i \qquad (1)$$

The carbon factor k_i for aeroplanes (k_a) is 602 grammes per tonnes transported per km. While for road (k_r), rail (k_l) and sea (k_s) have an emission of 62, 22, 8 grammes respectively. For flexibility, we will assume road transportation as the main methods on land and we will not use railway travel in our case study. C will be also expressed in tonnes during this paper to simplify the the presentation, where 1 tonne = 1 million grammes.

Let's assume Figure 4 presents a generic transportation between point (*M*) in Makkah and point (*E*) where point (*M*) is the start of the load (Zamzam water) journey to the airport and point (*E*) is the arrival airport destination. In this case, there are four main scenarios of carbon emission calculations.

*S*1 is the current scenario by aeroplane, *S*2 is the scenario where the Zamzam water is transported to a sea port in Saudi Arabia and then to an airport near the seaport, where the road journey is relatively short; *S*3 is the scenario where the airport is away from the seaport, and a significant journey by road is need; the fourth scenario and *S*4 is when the journey is all possible by road.

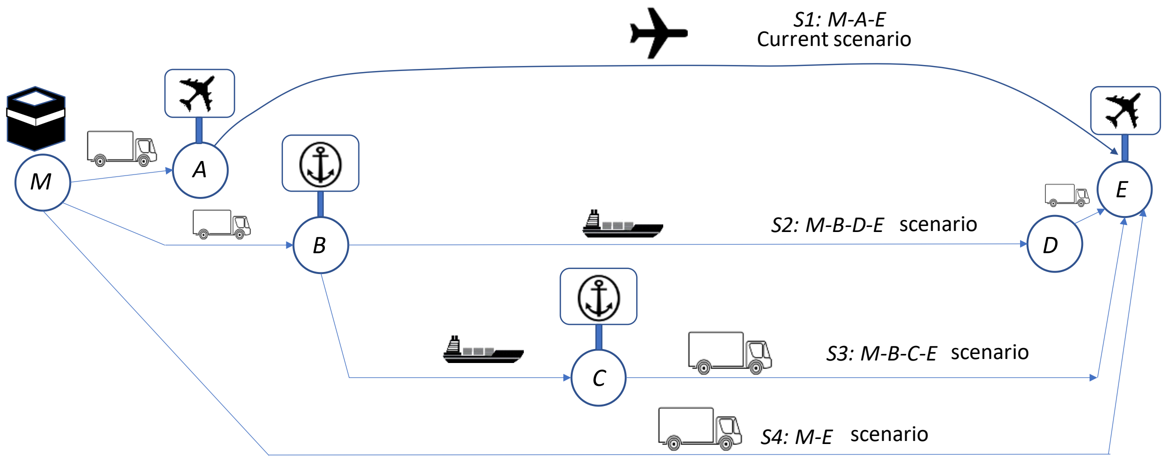

Figure 4: The four main scenarios of Zamzam water transportation

For the current scenario (S1) as in Figure 4, applying equation (1) leads to:

$$C_{S1} = C_{M\to A\to E} = w(k_r d_r + k_a d_a) \qquad (2)$$

Where k_r *and* d_r are the carbon factor by road and distance travelled by road respectively; and k_a is the carbon factor for air travel and d_a is flight distance.

And similarly,

$$C_{S2} = C_{M\to B\to D\to E} = w(k_r d_r + k_s d_s + k_r d_r) \qquad (3)$$

Where k_s *and* d_s are the carbon factor by sea and distance travelled by sea respectively.

For the third scenario,

$$C_{S3} = C_{M\to B\to C\to E} = w(k_r d_r + k_s d_s + k_r d_r) \qquad (4)$$

Equation (4) is similar to equation (3), but in this case the distance from *C* to *E* is much further on road in comparison to *S*2.

For road travel, *S*4 Carbon emission can be expressed as:

$$C_{S4} = C_{M\to E} = w(k_r d_r) \qquad (5)$$

Worst-case scenario is defined as the maximum of (C_{S2}, C_{S3}, C_{S4}); while Best-case scenario is defined as the minimum of (C_{S2}, C_{S3}, C_{S4}), when the group of scenarios are possible. Each generic scenario could have several implementations (alternatives) depending on available air, sea and land routes.

4. Case Study and Analysis Techniques

Let's consider Pakistan as a case study to explain the methodology in detail. In year 1439H, (corresponding to Sept 2017 until Aug 2018), in total 1,802,343 Hajj and Umrah travellers from Pakistan arrived to Saudi Arabia at two airports; Jeddah's King Abdul Aziz International Airport (KAIA, IATA JED) and Madinah's Prince Mohammed Bin Abdulaziz International Airport (PMIA, IATA MED). Sea travelling via Jeddah Islamic Port (SAJED) has shown no movement of travellers from Pakistan.

According to 2017 census, Karachi and Lahore are the two most populous cities in Pakistan with 14.9 million and 11.1 million inhabitants respectively. Karachi is located on the Arabian Sea and has a major seaport. Lahore is located in the eastern part of the country far from the sea, it can only be reached by air or road. Table 3 presents the relevant routes between Makkah, Medinah and Jeddah in Saudi Arabia from one side, and Karachi and Lahore in Pakistan on the other side; while Table 4 shows the number of returning Hajj and Umrah travellers to Pakistan from JED and MED and the estimated weight of Zamzam water at one 5kg-container per passenger. The carbon emission for each mode of transportation air, road and sea is considered to be 0.6, 0.066 and 0.008 Kg CO2 per tonne per km respectively.

Table 3: The transportation network between Saudi Arabia and Pakistan

Route	**From**	**To**	**Mode**	**Distance (km)**
1	Makkah City Centre	Jeddah Airport (JED)	Road	89
2	Makkah City Centre	Medinah Airport (MED)	Road	467
3	Medinah Airport (MED)	Lahore Airport (LHI)	Air	3477
4	Medinah Airport (MED)	Karachi Airport (KHI)	Air	2757
5	Jeddah Airport (JED)	Lahore Airport (LHI)	Air	3652
6	Jeddah Airport (JED)	Karachi Airport (KHI)	Air	2864
7	Makkah City Centre	Jeddah Seaport (SAJED)	Road	89
8	Jeddah seaport (SAJED)	Karachi Seaport (PKBQM)	Sea	4011
9	Karachi Seaport (PKBQM)	Karachi Airport (KHI)	Road	22
10	Karachi Airport (KHI)	Lahore Airport (LHI)	Road	1260

Table 4: The number of returning Hajj and Umrah travellers to Pakistan from JED and MED and estimated weight of Zamzam water at one 5kg-container per passenger.

Airport	**Number of Hajj & Umrah Travellers**	**Percentage**	**Weight of water (tonnes)**
MED	672,588	37%	3363
JED	1,129,755	63%	5649
Total	**1,802,343**	**100%**	**9012**

As discussed above, the analysis proposed for carbon emission in this paper is based on two types of scenarios; worst case scenario (WCS) and best case scenarios (BCS). The WCS assumes all passengers will fly to the nearest airport near the sea side to estimate resulting CO2 emissions. The BCS assumes all passengers flew to the furthest airport in-land and estimates resulting CO2 emissions. In both scenarios, emissions are estimated for current modes of transportation and for the proposed alternatives. Reduction in CO2 emissions are then calculated. Figure 5-a illustrates the current transportation model for the case study of Pakistan, while Figure 5-b presents the new proposed transportation model. Figure 6 shows various routes and mode of transport considered for this case study. Table 5 presents the calculations of the estimated tonnes of CO2 emitted for best and worst case scenarios and the level of carbon savings.

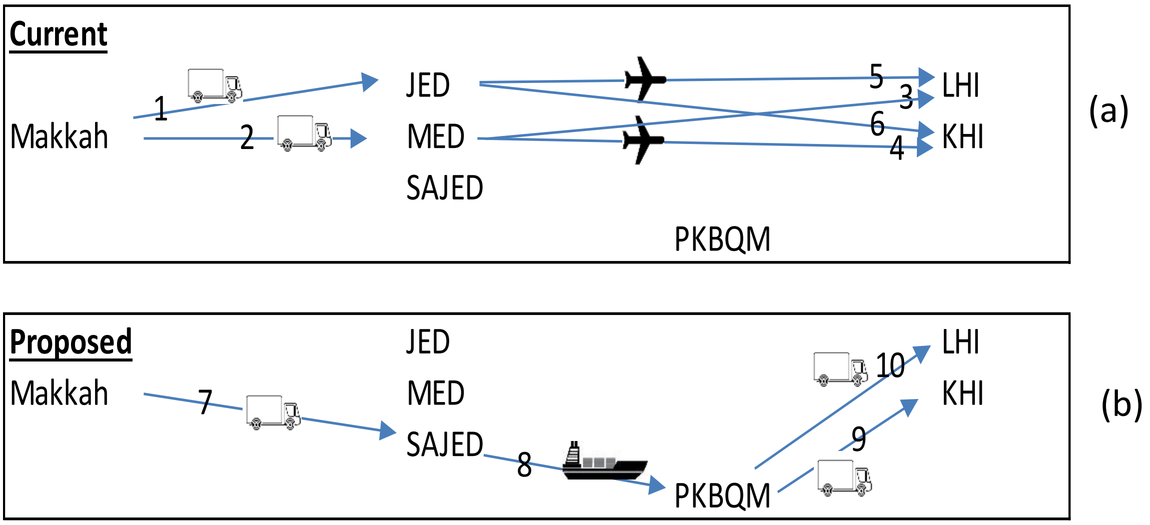

Figure 5: The current (a), and proposed (b) transportation models for the case study of Pakistan.

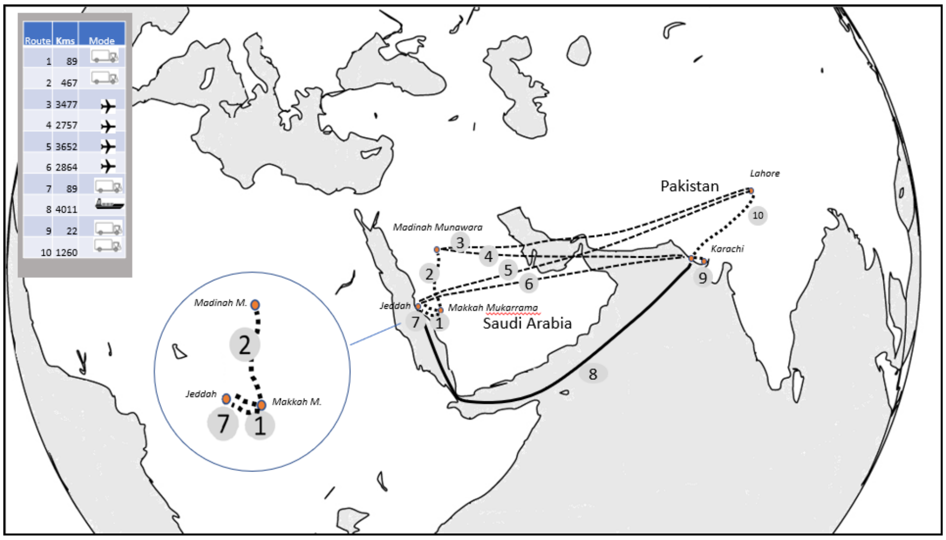

Figure 6: The various possible routes and modes of transport considered for the case study of Pakistan.

Table 5: The estimated tonnes of CO2 emitted for best and worst case scenarios for carbon savings.

Route	From	To	Mode of Travel	Distance	CO2 rate/ton km	Weight (tons)	Tonnes CO2	Current Worst-case	Alternative Worst-case	Current Best-case	Alternative Best-case
1	Makkah	JED		89	0.000062	5649	31	X		X	
2	Makkah	MED		467	0.000062	3363	97	X		X	
3	MED	LHI		3477	0.000600	3363	7,016	X			
4	MED	KHI		2757	0.000600	3363	5,563			X	
5	JED	LHI		3652	0.000600	5649	12,378	X			
6	JED	KHI		2864	0.000600	5649	9,707			X	
7	Makkah	SAJED		89	0.000062	9012	50		X		X
8	SAJED	PKBQM		4011	0.000008	9012	289		X		X
9	PKBQM	LHI		1260	0.000062	9012	704		X		
10	PKBQM	KHI		22	0.000062	9012	12				X
						Total Tonnes CO2		19,522	1,043	15,398	351
						Saving CO2 %		95%		98%	

4.1 Worst-Case Scenario in Carbon Emission

In the Current Worst-Case Scenario assumes, in this case, that all passengers will fly back to the furthest major city in-land in Pakistan, which is Lahore (airport LHI). Hence this scenario is also named 'Far' Scenario. From MED and JED airports, 672,588 and 1,129,755 passengers respectively are assumed to fly back to LHI. At a rate of 5kg of water per passenger, the respective estimated total weight of water transported by air is 3,363 tonnes and 5,649 tonnes from MED and JED respectively. The rates of CO2 emission used for air, land, and sea modes of transport were 600, 62, and 8 kg of CO2 per tonne weight per km travelled. Factoring in the shipping distances by air, land, and sea, from both MED and JED to LHI, result in CO2 emission in tonnes/tonne weight for the routes concerned as shown in Table 5 ('Tonnes CO2/T').

The current Worst-Case Scenario involves transporting water from Makkah to JED and to MED by truck, and from JED and MED to LHI by air. The total amount of emitted CO2 for Worst-Case Scenario is estimated to be 19,552 tonnes. The Alternative Worst-Case Scenario in carbon emission proposes alternative routes and modes of transport to reduce carbon emissions from the current scenario. In the case of Pakistan, it is assumed that water is transported from Makkah to Jeddah Islamic Port (SAJED) by truck over an 89km road most of which is motorway and then shipped to Karachi seaport (PKBQM) over water, a distance of 4011km. Water containers are then shipped to the airport in Lahore (LHI) by truck over a 1260km road. The estimated CO2 emissions of the proposed alternative is 1043 tonnes.

4.2 Best-Case Scenario in Carbon Emission

Current Best-Case Scenario assumes, in this case, all passengers will fly back to the nearest city in Pakistan on the seaside, which is Karachi (airport KHI); hence this scenario is also called 'Near' Scenario. From MED and JED airports, 672,588 and 1,129,755 passengers respectively are assumed to fly back to KHI. At a rate of 5kg of water per passenger, the estimated total weight of water transported by air is 3363 tonnes and 5649 tonnes from MED and JED respectively. Factoring in shipping distances by air, land, and sea, from both MED and JED to KHI, resulted in CO2 tonnes/tonne weight for the route concerned as shown in Table 5.

The Current Best-Case Scenario involves transporting water from Makkah to JED and to MED by truck, and from JED and MED to KHI by air. The total amount of emitted CO2 for Current Best-Case Scenario is estimated to be 15,358 tonnes. The proposed Best-Case suggests alternative routes and modes of transport to reduce carbon emissions. In the case of Pakistan, it proposes that water containers are to be transported from Makkah to SAJED by truck, and then shipped to Karachi seaport (PKBQM) over water, a distance of 4011km. Water containers are then shipped by truck 22km away to the nearby airport (KHI). The estimated CO2 emissions of the proposed alternative is 351 tonnes.

4.3. Comparison between the scenarios

In the case study of Pakistan, the results of the four scenarios explained above are summarised in Table 6. When compared with current routes and modes of transport, the proposed alternative routes and modes of transport offer a less polluting option resulting in massive reduction of CO2. It has been estimated that carbon savings for the case of passengers from Pakistan will be in the region of 95 to 98%, which is significant level of reduction.

Table 6: The carbon savings in the case study of Pakistan for worst and base case of carbon emissions scenarios.

	Current WCS	Proposed WCS	Current BCS	Proposed BCS
Total CO2 (tonnes)	19522	1043	15398	351
Saving CO2 (tonnes)	95%		98%	

5. Results and Discussion

Table 7 presents the carbon emission savings for the top 10 countries with 77% of passengers for Hajj and Umrah. The actual figures and calculations are presented in Appendix A. Figure 7 presents a summary of the findings where the carbon savings in the case of Indonesia and Bangladesh could reach 99.1% and 99.2% respectively. Hence, the further away the passenger flies, the more savings it could be achieved. In the case of Egypt, UAE, and Iraq the savings could be less due to the close proximity and for the possibility of pilgrims using road travel by buses combined with sea travel as in the case of Egypt. The results show CO2 savings of more than 96% in most cases.

Table 7: CO2 savings by mode of transportation using best and worst case scenarios.

	Country of destination	Pakistan	Indonesia	India	Turkey	Egypt	Algeria	Malaysia	UAE	Bangladesh	Iraq
City (BCS)	CO2 tonnes by Air	0.0037	0.0377	0.0201	1,776.9071	973.9438	756.3444	4,500.0679	530.2745	6,415.3872	1,830.2456
	CO2 tonnes by Sea	0.0000	0.0003	0.0001	22.5067	5.7126	3.4879	29.9019	4.2761	36.1623	28.8323
	CO2 tonnes by Land	0.0000	0.0000	0.0000	34.3237	8.4186	0.7015	7.6016	1.1697	3.8151	4.4400
	CO2 Tonne Saving	0.0036	0.0373	0.0199	1,725.3253	878.9410	744.1249	4,452.3336	497.5521	6,348.4552	1,687.3660
	CO2 % tonne Saving	0.9774	0.9895	0.9869	0.9710	0.9025	0.9838	0.9894	0.9383	0.9896	0.9219
City (WCS)	CO2 tonnes by Air	0.0046	0.0407	0.0220	2,001.9902	1,125.3165	825.9988	4,759.9116	566.5351	6,215.8569	2,304.5279
	CO2 tonnes by Sea	0.0000	0.0003	0.0002	22.5067	7.8949	3.7950	32.2239	4.1363	36.1623	28.8323
	CO2 tonnes by Land	0.0001	0.0000	0.0002	7.2392	5.1865	0.6819	4.1886	0.9247	13.2031	46.5294
	CO2 Tonne Saving	0.0045	0.0404	0.0216	1,972.2443	1,112.2352	821.5220	4,723.4991	561.4740	6,166.4915	2,229.1662
	CO2 % tonne Saving	0.9782	0.9918	0.9818	0.9851	0.9884	0.9946	0.9924	0.9911	0.9921	0.9673

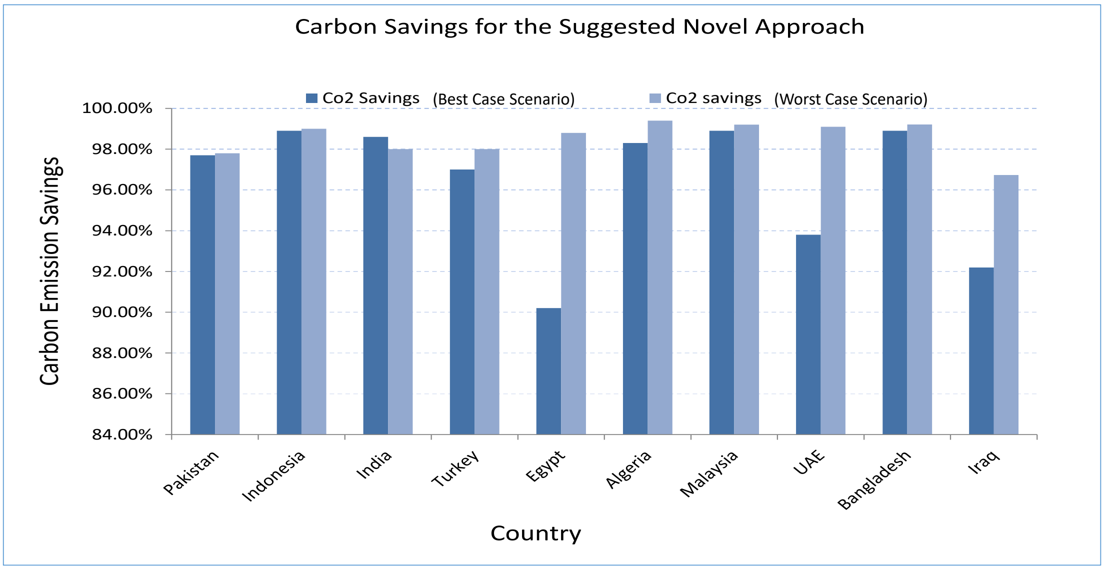

Figure 7: Range of carbon savings for each country of the top 77% passengers**.**

However, many cultural and organisational factors should be taken into consideration when adopting the proposed approach. For example, passengers might object to not physically carrying with them Zamzam water as it removes the excitement of taking such holy gift to family and friends. Also, the freshness of the water is a factor that most people will consider. But, given that most countries import food and bottled water by sea and road, the availability of cooled containers would allow the freshness of water at the arrival destination. The other challenge is managing such process and guaranteeing the delivery of water which will need significant budget and coordination process in several countries. But overall, this is a challenge worth taking to allow the reduction in carbon emission and at the same time maintain the high level of service to pilgrims.

Conclusion

Millions of people visit Saudi Arabia (Makkah and Madinah) for Hajj and Umrah as part of Muslims religious activities. The most valued gift people take home with them to friends and family is the holy water of Zamzam. The 5-Litre specially packaged water container is used for this purpose. Most pilgrims use air transportation and carry with them Zamzam water gift. Some airlines provide this service for free. This paper has discussed the carbon emission cost to transport this excess weight by air. It has proposed a novel approach of transporting the water to destination by sea and/or road ahead of time to be ready for collection upon the arrival of the passenger at the home destination airport. Applying the strategy for the main countries making a share of the 77% of passengers, could result in an annual saving of more than 81 thousand tonnes of CO2 with an estimated reduction of more than 96% tonnes of CO2.

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Appendix A

Table A1: Travel by air carbon emission with best and worst case scenarios.

			Country of destination	Pakistan	Indonesia	India	Turkey	Egypt	Algeria	Malaysia	UAE	Bangladesh	Iraq
Airport	(Near) BCS		City (Near)	Karachi	Jakarta	Mumbai	Ankara	Cairo	Boumerdè	Ipoh	Abu Dhabi	Chittagong	Basra
		PMIA	PMIA to Near Airport (kms)	2,757.00	8,021.00	3,473.00	1,822.00	1,036.00	3,700.00	6,912.00	1,485.00	5,294.00	1,034.00
			Tonnes CO2/T PMIA to Near Aiport	1.65	4.81	2.08	1.09	0.62	2.22	4.15	0.89	3.18	0.62
			Tonnes CO2 PMIA to Near Airport	0.00	0.02	0.01	969.72	497.48	651.79	2,101.46	436.34	2,684.69	828.18
		KAIA	KAIA to Near Airport	2,864.00	7,992.00	3,523.00	2,110.00	1,220.00	3,821.00	6,927.00	1,587.00	5,403.00	1,302.00
			Tonnes CO2/T KAIA to Near Aiport	1.72	4.80	2.11	1.27	0.73	2.29	4.16	0.95	3.24	0.78
			Tonnes CO2 KAIA to Near Airport	0.00	0.02	0.01	778.11	449.90	95.82	2,380.77	79.30	3,699.93	956.65
Airport	(Far) WCS		City (Far)	Lahore	Surabaya	New Delhi	Istanbul	Alexandria	Oran	Iskandar P	Sharjah	Dhaka	Nineveh
		PMIA	PMIA to Airport Far (kms)	3,477.00	8,656.00	3,747.00	2,080.00	1,213.00	4,048.00	7,319.00	1,588.00	5,122.00	1,317.00
			Tonnes CO2/T PMIA to Airport Far	2.09	5.19	2.25	1.25	0.73	2.43	4.39	0.95	3.07	0.79
			Tonnes CO2 PMIA to Airport Far	0.00	0.02	0.01	1,107.04	582.47	713.10	2,225.20	466.61	2,597.46	1,054.85
		KAIA	KAIA to Airport Far	3,652.00	8,637.00	3,894.00	2,348.00	1,400.00	4,154.00	7,323.00	1,707.00	5,239.00	1,639.00
			Tonnes CO2T/ KAIA to Airport Far	2.19	5.18	2.34	1.41	0.84	2.49	4.39	1.02	3.14	0.98
			Tonnes CO2 KAIA to Airport Far	0.00	0.02	0.01	865.88	516.28	104.17	2,516.87	85.29	3,587.62	1,204.27

Table A2: Travel by land carbon emission with best and worst case scenarios.

Mode			**Country of destination**	**Pakistan**	**Indonesia**	**India**	**Turkey**	**Egypt**	**Algeria**	**Malaysia**	**UAE**	**Bangladesh**	**Iraq**
			City (BCS) (Near)	**Karachi**	**Jakarta**	**Mumbai**	**Ankara**	**Cairo**	**Boumerdès**	**Ipoh**	**Abu Dhabi**	**Chittagong**	**Basra**
Land	Makkah to Saudi Airports	PMIA	Makkah to PMIA (kms)	467.00	467.00	467.00	467.00	467.00	467.00	467.00	467.00	467.00	467.00
			Tonnes CO2/T Makkah to PMIA by Land	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
			Tonnes CO2 Makkah to PMIA by Land	0.00	0.00	0.00	25.68	23.17	8.50	14.67	14.18	24.47	38.65
		KAIA	Makkah to KAIA (kms)	89.00	89.00	89.00	89.00	89.00	89.00	89.00	89.00	89.00	89.00
			Tonnes CO2/T Makkah to KAIA by Land	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
			Tonnes CO2 Makkah to KAIA by Land	0.00	0.00	0.00	3.39	3.39	0.23	3.16	0.46	6.30	6.76
			City (WCS) (FAR)	**Lahore**	**Surabaya**	**New Delhi**	**Istanbul**	**Alexandria**	**Oran**	**Iskandar Pute**	**Sharjah**	**Dhaka**	**Nineveh**
Land	Far		Seaport Far to Airport Far by Land (kms)	1,260.00	38.00	1,088.00	27.00	49.00	15.00	46.00	28.00	264.00	938.00
			Tonnes CO2/T Seaport Far to Airport far by Land	0.08	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.02	0.06
			Tonnes CO2 Seaport Far to Airport far by Land	0.00	0.00	0.00	1.68	1.84	0.10	1.43	0.22	9.87	42.50
			Makkah to Airport Far by Land (kms)					1,913.00			1,884.00		2,295.00
			Tonnes CO2/T Makkah to Airport Far by Land	0.00	0.00	0.00	0.00	0.12	0.00	0.00	0.12	0.00	0.14
			Tonnes CO2 Makkah to Airport Far by Land	0.00	0.00	0.00	0.00	71.90	0.00	0.00	14.89	0.00	103.98

Table A3: Carbon emission by sea transport with best and worst case scenarios.

	Country of destination	**Pakistan**	**Indonesia**	**India**	**Turkey**	**Egypt**	**Algeria**	**Malaysia**	**UAE**	**Bangladesh**	**Iraq**
Seaport (near)	**Seaport (BCS)**	**Karachi**	**Port of Tanjung Priok Jakarta**	**Mumbai**	**Port of Istanbul**	**Adabiya**	**Algiers**	**Butterworth**	**Abu Dhabi**	**Chittagong Port**	**Basra**
	JIP-Seaport Near (NM)	2,166.00	4,583.00	2,353.00	1,509.00	636.00	2,226.00	4,033.00	2,264.00	4,046.00	2,663.00
	JIP-Seaport Near (kms)	4,011.00	8,488.00	4,358.00	2,795.00	1,178.00	4,123.00	7,469.00	4,193.00	7,493.00	4,932.00
	Tonnes CO2/T JIP-Seaport Near	0.03	0.07	0.03	0.02	0.01	0.03	0.06	0.03	0.06	0.04
	Tonnes CO2 JIP to Seaport Near	0.00	0.00	0.00	22.51	5.71	3.49	29.90	4.28	36.16	28.83
Seaport (far)	**Seaport (WCS)**	**Karachi**	**Surabaya**	**Kandla**	**Port of Istanbul**	**Alexandria**	**Oran**	**Johor**	**Sharjah**	**Chittagong Port**	**Basra**
	JIP-Seaport Far (NM)	2,166.00	4,959.00	4,033.00	1,509.00	879.00	2,422.00	4,346.00	2,190.00	4,046.00	2,663.00
	JIP-Seaport Far (kms)	4,011.00	9,184.00	7,469.00	2,795.00	1,628.00	4,486.00	8,049.00	4,056.00	7,493.00	4,932.00
	Tonnes CO2/T JIP-Seaport Far	0.03	0.07	0.06	0.02	0.01	0.04	0.06	0.03	0.06	0.04
	Tonnes CO2 JIP to Seaport Far	0.00	0.00	0.00	22.51	7.89	3.80	32.22	4.14	36.16	28.83