Solid Waste Management and Recycling During Hajj Pilgrimage in Mina

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Declaration

The candidate confirms that the work submitted is his/her own and that appropriate credit has been given where reference has been made to the work of others.

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Abstract

Hajj, one of the world's biggest pilgrimages for Muslims, takes place in Makkah, Saudi Arabia. Annually, about four million pilgrims gather in sacred places in Makkah to perform Hajj, spending most of the time (4-5 days) in a place called Mina where they generate about 17 kt of solid waste. This quantity is disposed of in Makkah landfill without any treatment or resource recovery. Therefore, this research aims to study and assess the current SWM in Mina and identify the main challenges, with a view to investigating the possibility of introducing recycling scheme. The current situation of SWM in Mina was assessed: (i) based on the Wasteaware ISWM benchmark indicators; (ii) through comparison with other mega events; and (iii) via the opinion of main stakeholders (questionnaires). Based on this assessment, a pilot recycling scheme was introduced through an exemplar project, implemented in three camps in Mina, where pilgrims were asked to sort their plastic waste into provided sorting bins. Subsequently, pilgrims' recycling intention was compared with their actual behaviour to estimate the predictive accuracy of the stated intention. An econometric (logit) model was developed to identify factors affect pilgrims' recycling intention and to predict future behaviour based on stated intention.

It is concluded that the key weaknesses in SWM in Mina are the lack of controlled waste disposal, the lack of waste recovery or recycling, and the current national SWM strategy's insufficiency regarding environmental protection. The exemplar project demonstrated that recycling is feasible. The average recycling rate was at 25% wt. with no practical difference between the group practicing recycling at home and other that do not. An adjusted stated intention was calculated to enable predicting future pilgrims' recycling behaviour. The overall predictive accuracy of the pilgrims' stated intention was at 79%, denoting a strong relationship between the pilgrims' actual behaviour and stated intention. Based on the econometric model, it is concluded that mainly level of education ($p = 0.0001$), socio-demographic factors, ethnicity ($p = 0.019$), and recycling habit ($p = 0.013$) have an effect on pilgrims' recycling intention, if recycling is imposed by law (compulsory).

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List of Abbreviations

DPC	Disposed plastic in the compactor box
EC	Egyptian camp in the exemplar project
EPI	Environmental performance index
GDP	Gross domestic product
GNI	Gross national income
HDI	Human development index
IRS	Informal recycling sector
ISWM	Integrated sustainable waste management
MCW	Minimum compactor box weight
MSP	Maximum daily weight that can be sorted in the green bins
MSW	Municipal solid waste
MSWM	Municipal solid waste management
PC	Pakistani camp
PASI	Predictive accuracy of the stated intention
SPC	Sorted plastic in the contaminated sorting bags
SPU	Sorted plastic in the uncontaminated sorting bags
SWM	Solid waste management
TGP	Total generated plastic in the camp
TGW	Total generated waste in the camp (waste in the compactor box + sorted plastic)
TPB	Theory of planned behaviour
TSPS	Total sorted plastic based on the second scenario
TWC	Total waste in the compactor box
WCE	Total weight of the waste on the centre of the street
WEAC	Western European and Australian camp in the exemplar project
WL	Total weight of the waste on the left edge of the street
WR	Total weight of the waste on the right edge of the street
XCW	Maximum compactor box weight

List of Notations

β_1	The intercept
β_i	Slope coefficients
C	Confidence interval
N	The final sample size
NB	Number of waste bags in the compactor box
Np	Primary sample size
Tp	Total population
P_i	Probability of pilgrims' positive sorting intention, ranging between 0 and 1
PV	Daily provided volume for sorting
SD	Standard deviation
SE	Standard error
X_i	The independent variables
Z	=1.96 at level of confidence = 95%
%	Means wt. % as received unless stated another way

CHAPTER I

BACKGROUND

1-1 Introduction

Solid waste management (SWM) has changed considerably over the past two to three decades; it is no longer merely the process of collecting waste and disposing of it in a landfill. As Eriksson et al. (2005) reported, SWM is developing continuously, where waste disposal in landfills should be minimized while the resource recovery by recycling materials and energy must be increased. This can help in lowering the resource depletion, energy consumption, economic costs, and environmental impact (Eriksson et al., 2005). All of these, in addition to controlling the waste generation rate, will lead to sustainable and environmentally sound SWM, a method which is followed in many of the developed countries (Koroneos and Nanaki, 2012).

However, this is not the case in many developing countries, where waste is collected and disposed of in a landfill or even in an open dump without any treatment or resource recovery (Gardia et al., 2006).

Saudi Arabia is considered as a developing country especially in environmental terms. Some of the main cities in Saudi Arabia have better SWM than have others, with recycling considered as a method to decrease the use of landfill (**Section 1-5**). However, Makkah city (where the Hajj takes place) is not one of these cities; instead, waste is collected and disposed of in Makkah landfill by Makkah Municipality without any treatment.

Makkah city is the capital of Islam because of the holy mosque and the sacred places where the Hajj takes place, and so it is a destination for all Muslims around the world. Each year, about 4 million of the word's 1.65 billion Muslims (Kettani, 2010) make the pilgrimage (Hajj) to the sacred places in Makkah city (**Section 1-2**). This makes Hajj event management and organization more challenging than other mega events.

The municipal solid waste (MSW) produced during the Hajj is managed by Makkah Municipality. This has caused SWM in Hajj to be as poor as SWM in Makkah city where all collected waste is disposed of in the Makkah landfill. This means that, to date, appropriate SWM and effective resource recovery have not been considered as an important dimension in the organization and management of the Hajj. Therefore, this research will focus on assessing the current SWM in Mina and the need to introduce recycling (**Section 3-2**).

1-2 Hajj and Mina

The Hajj is the world's biggest pilgrimage event for Muslims, and it takes place in Makkah city in Saudi Arabia. It is the fifth pillar of the Islamic faith, and all Muslims must make the effort to perform Hajj at least once, if possible. Moreover, the Saudi Arabian government allows the performance of Hajj once every five years for individuals. The number of pilgrims from each country or region around the world who are allowed to perform Hajj every year is limited based on the ratio of 1000 pilgrims for each million Muslims for each country (Ministry of Hajj, 2010).

The Hajj is an annual event that happens in the last month of the Arabic calendar (Dhu al-Hijjah). Pilgrims need at least five days to complete all the Hajj duties, and they usually spend between ten and forty days in Makkah. They do some of the Hajj rites in Makkah and the remainder in a place called Almashaaer Almuqaddassah (sacred sites), which is very close to Makkah city and occupies an area of 33 km^2 (Makkah Municipality, 2010). Almashaaer Almuqaddassah is further divided into three areas (**Figure 1-1**): Mina (8 km^2), Arafat (13 km^2), and Muzdalifah (12 km^2) (Makkah Municipality, 2010). Pilgrims spend their first day in Mina, then spend 12 hours in Arafat and 12 hours in Muzdalifah and, finally, they return to Mina for three to four days, as shown in the Hajj map in **Figure 1-2**.

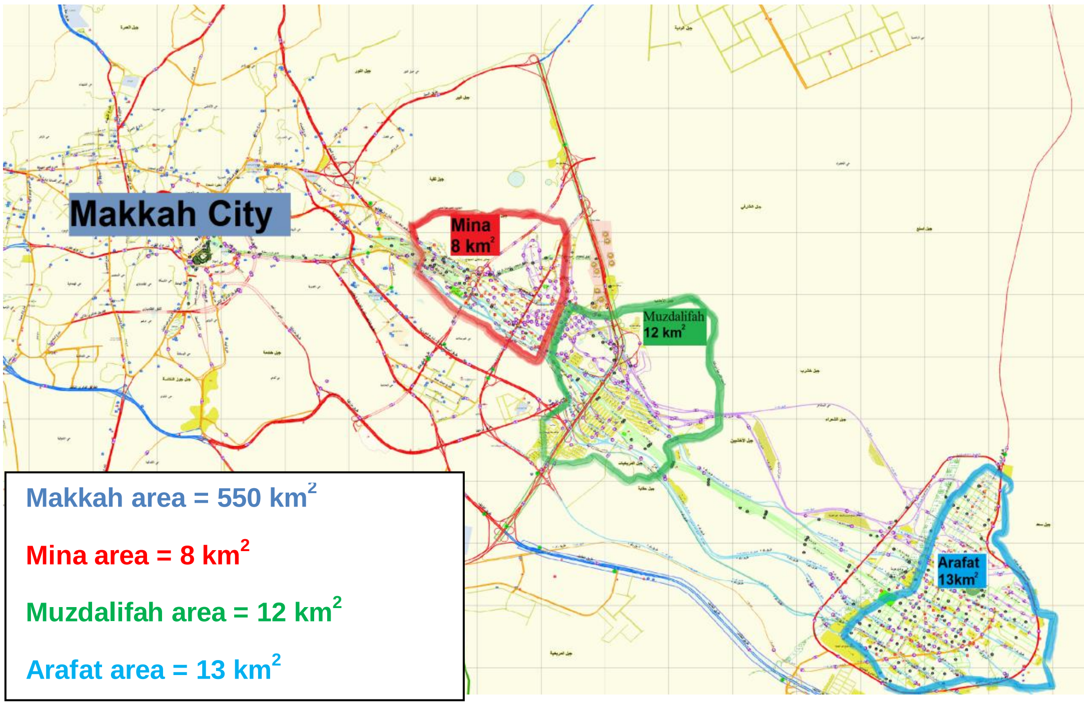

Figure 1-1 Makkah and sacred sites map. Adapted from Hajj GIS (2010)

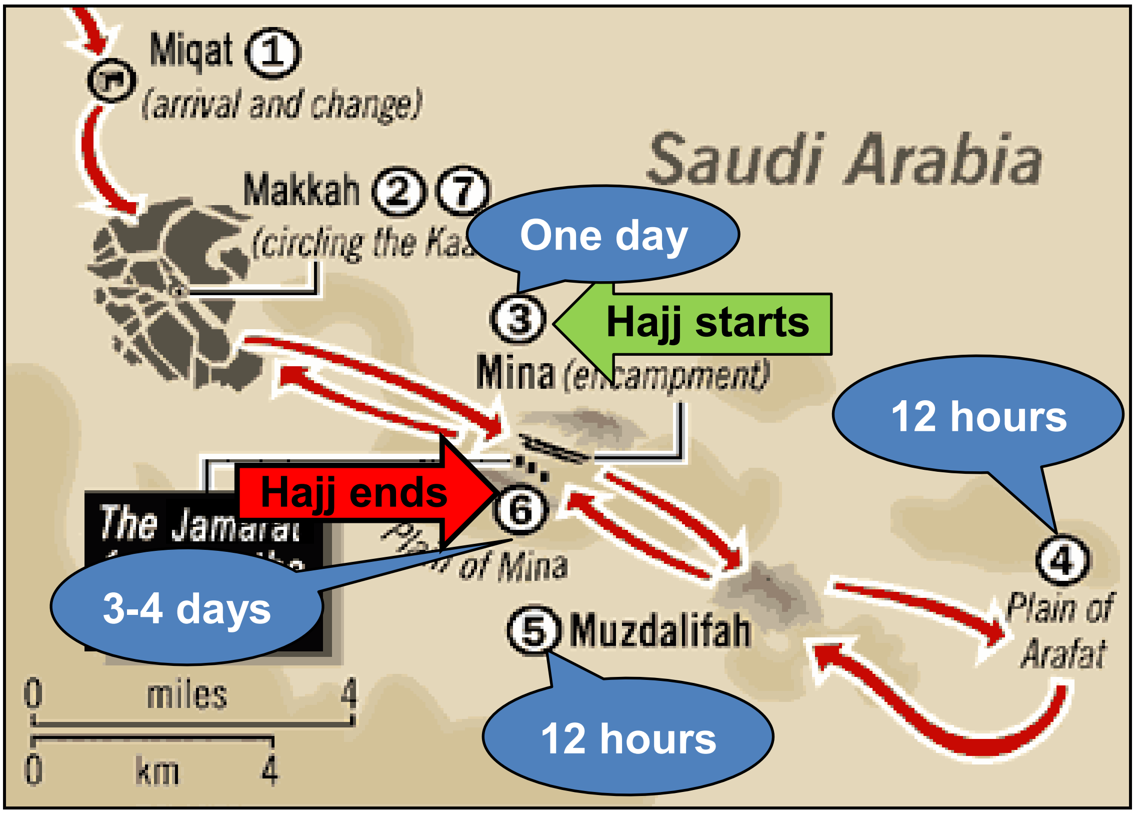

Figure 1-2 Hajj map. Adapted from IEC (2012)

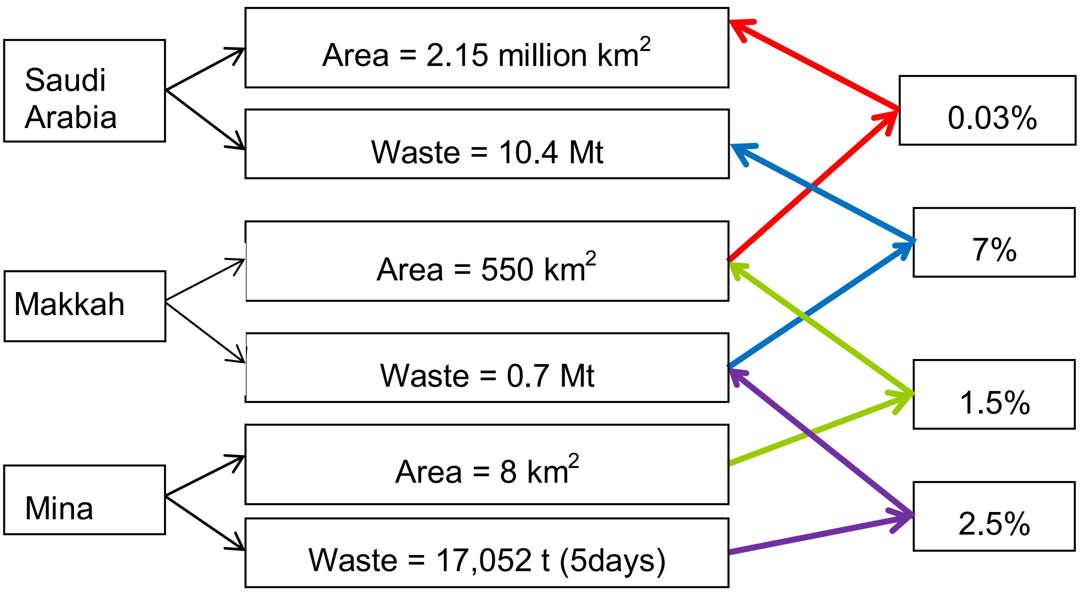

Figure 1-3 A comparison (as a percentage) between Saudi Arabia, Makkah and Mina areas and the quantity of disposed solid waste in the landfill

However, only 60% (4.8 km^2) of the Mina area is actually used; the rest is not used because of its high mountains (Makkah Municipality, 2010). The used area of Mina is divided into zones and squares that can be changed according to the number of pilgrims of each nationality. Each square has several camps, within which there are several tents, toilets, a kitchen and a waste compactor box, and the combined area of all the camps is 2.07 km^2, which represents 25.9% of the total area of Mina (43.1% of the used area). The remaining area consists of bus stops, roads, services (food shops, public toilets, drinking water taps, and streets waste compactor boxes), hospitals, the Aljamarat Bridge, mosques, and Mina authorities camps.

There are seven organizations, called Tawafa Companies, which are responsible for pilgrims, and each serves multiple countries from all over the world, as seen in **Table 1-1** (Ministry of Hajj, 2011). In addition, they have 723 offices, called field service offices, situated in the Mina camps (Ministry of Hajj, 2010). Each camp consists of a different number of fire-resistant tents (which vary between 16 m^2 and 96 m^2 in area), one kitchen, toilets, and a waste compactor box (ibid). **Figure 1-4** shows how Mina is divided into different sized camps while **Figure 1-5** illustrates an example of how these camps are divided.

In 2011, about 2.93 million legal pilgrims performed Hajj (CDSI, 2011), whereas more than one million illegal pilgrims fulfilled this duty in the same year (Alkhedheiri, 2012). These illegal pilgrims all came from the Saudi Arabian cities, but some were not legal Saudi citizens). **Figure 1-6** shows the trend in the number of legal and illegal pilgrims between 2008 and 2011 (Alkhedheiri, 2012; CDSI, 2012).

Figure 1-4 Part of Mina camps and white tents. Adapted from Daily Mail Reporter (2010)

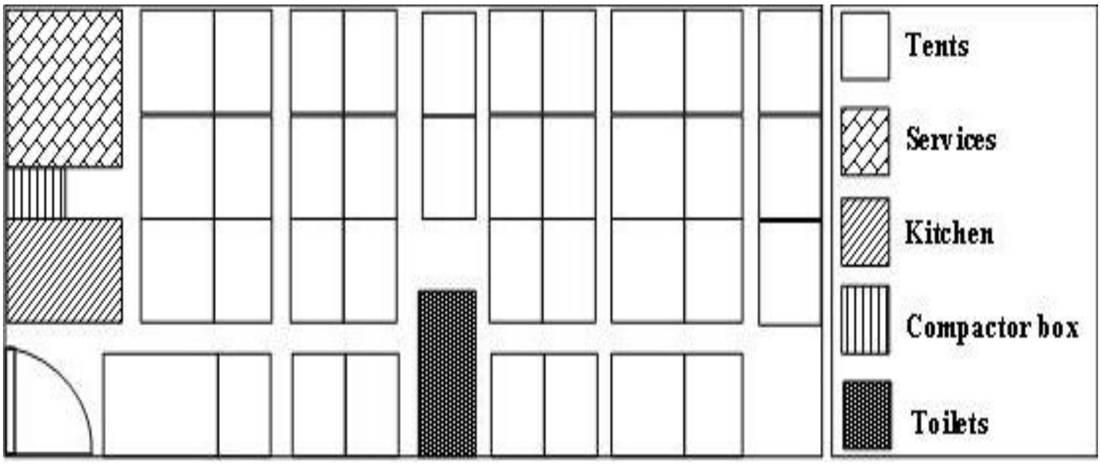

Figure 1-5 An example of the design of one of Mina camps. Adapted from Ministry of Hajj (2010)

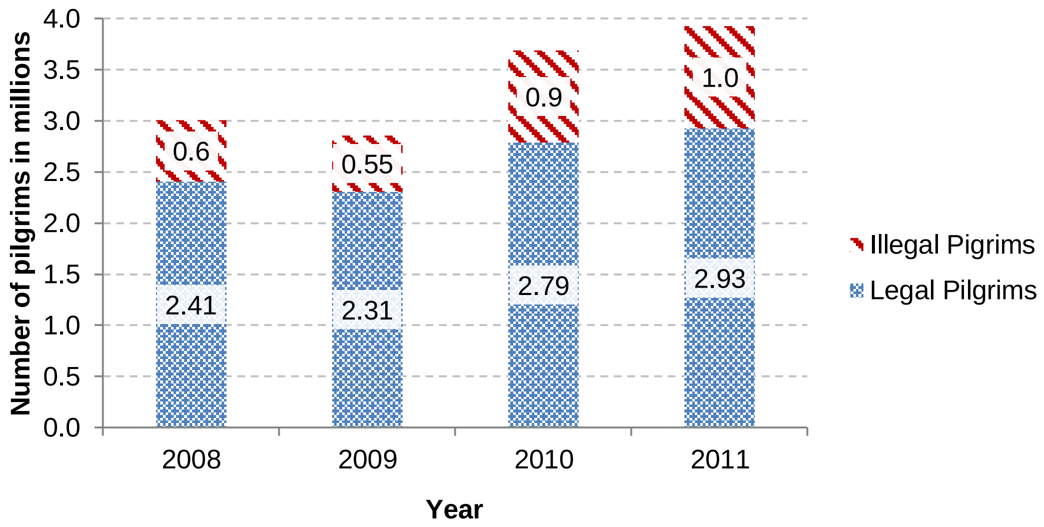

Figure 1-6 Numbers of legal and illegal pilgrims between 2008 and 2011

Table 1-1 The number of pilgrims and the countries served by each Tawafa Company (Ministry of Hajj, 2011; CDSI, 2012)

Tawafa Company	Number of pilgrims in 2010	Served countries
South Asia	498,335	Pakistan, India, Bangladesh, Afghanistan, Sri Lanka, Myanmar, Maldives, Nepal, Bhutan and those who have the same nationality, living in the GCC countries.
Non-Arab African countries	179,650	Nigeria, Niger, South Africa, Chad, Togo, Ivory Coast, Mali, Gambia, Liberia, Central Africa, Cameroon, Guinea, Guyana, Ghana, Guinea-Bissau, Tanzania, Sierra Leone, Burkina Faso, Senegal, Gabon, Mauritius, Ethiopia, Kenya, Uganda, Benin, Madagascar, Seychelles, Rwanda, Burundi, Swaziland, Lesotho, Angola, Namibia, Zambia, Zimbabwe, Botswana, Equatorial Guinea, Congo, Democratic Congo, Reunion, Cape Verde Islands and St Helena Island.
South East Asia	302,440	Indonesia, Malaysia, Singapore, China, Thailand, Philippines, Brunei, Hong Kong, North and South Korea, China Taiwan, Japan, Cambodia and Fiji.
Arabian Countries	358,713	Tunisia, Egypt, Algeria, Sudan, Morocco, Yemen, the Emirates, Syria, Jordan, Libya, Lebanon, Mauritania, Palestine, Qatar, Oman, Kuwait, Somalia, Iraq, Comoro Island, Eritrea and Djibouti.
Turkey and Muslims of Europe, the Americas and Australia	261,789	Turkey and the Muslims of Europe, the Americas and Australia
Saudi Arabia	989,798	Saudi Arabian Pilgrims
Iran	109,370	Islamic Republic of Iran

1-3 Saudi Arabia

Saudi Arabia covers about 70% of the Arabian Peninsula with an area of 2,149,690 km^2 (SGS, 2012), making it the third largest country in the Middle East and the thirteenth largest state in the world (CIA, 2011). It is located in the south-western region of Asia; and the Tropic of Cancer crosses it in the middle (SGS, 2012).

In 1992, the total population of Saudi Arabia was 16.1 million, but by 2010 this had increased to 27.1 million with an annual growth rate of 3.2% (CDSI, 2010). In 2010, there were about 4,643,151 houses in Saudi Arabia distributed among 169 cities and villages with a population density of 14 people per square kilometre (ibid).

As mentioned in **Section 1-1**, Saudi Arabia is considered as a potential destination for more than 1.65 billion Muslims around the world (Kettani, 2010), because of Umrah (visiting the Holy Mosque of Makkah) and the Hajj. The Umrah period lasts for eight months and activity peaks in the ninth month of the Arabic calendar. For the Hajj, visitors are allowed to stay for a maximum of two months in Makkah, but activity peaks in the twelfth month of the Arabic calendar (Ministry of Hajj, 2011). In 2008, more than 7.74 million Muslims visited Makkah city to perform Umrah or Hajj, and it is expected that there will be more than 13.75 million visitors in 2019 (Plumb et al., 2010).As a result, the government of Saudi Arabia faces many major challenges, for instance, increasing the capacities of the two Holy Mosques, improving transportation facilities and infrastructures, and developing the social and environmental aspects (ibid).

However, because Saudi Arabia is a developing country, it needs to improve in many aspects, such as environmental issues and public services (**Section 2-5**). Recently, Saudi Arabia started to be concerned about its environment because of the increasing pollution as well as the increasing number of visitors. Therefore, in 2010, the Saudi government spent about \$12.2 billion to improve the infrastructure and \$5.8 billion to improve municipal services (Plumb et al., 2010).

1-4 Makkah City

Makkah city is the capital city of Islam, which means it is very busy throughout the year. It is located in the western region of Saudi Arabia, as shown in **Figure 1-7** (Plumb et al., 2010). Makkah covers an area of 550 km^2, of which 88 km^2 is populated by its citizens (1,675,368 in 2010) (CDSI, 2010; Makkah Municipality, 2010). The central area of Makkah, which covers an area of 6 km^2, is considered to be the busiest area in Makkah city throughout the year. This is where the Holy Mosque is located and where there are many hotels, especially five-star hotels (Makkah Municipality, 2010).

Figure 1-7 Saudi Arabia maps. Adapted from Plumb et al. (2010)

The city of Makkah is located in a valley (surrounded by mountains), which means it is wind-free zone (Halabi, 2006); the average wind speed in Makkah city is 2 knots (3.7 $km.hr^{-1}$), and it has an average relative humidity of 46.8% (CDSI, 2010). Its weather is usually hot with the average temperature ranging between 35°C and 45°C (ibid).

1-5 Solid Waste Management in Saudi Arabia

Mainly, SWM in Saudi Arabia, as in many developing countries, consists of four phases: waste generation, collection, transport and transfer, and disposal (MOMRA, 2009). There are no rules for waste sorting at source in Saudi Arabia, which leads the citizens to throw anything with their waste including household hazardous waste and bulky waste.

Usually, at the end of the day, people throw their daily waste into the waste containers that are distributed in the streets (**Figure 1-8**). At that time, waste pickers, who are usually illegal African citizens (**Figure 1-9**) or the cleaning contractors' workers (**Figure 1-10**), start to search in the waste containers to extract the recyclable materials (Alsebaei, 2007).

Usually, the street waste containers are emptied daily and sometimes twice a day throughout the week including holidays (MOMRA, 2009). This has resulted in an increasing expenditure on cleaning contracts (**Section 2-2-2**); a recent statistic showed that these contracts cost the Saudi government SR7.8 billion (GBP 1.3 billion or $2.1 billion) in 2013, and it is increasing every year by 5-8%. The contracts include the cost of waste collection and transportation and the operation of the landfill (MOMRA, 2013).

Figure 1.8 Streets waste containers in Makkah. Adapted from Cleaning Department (2010)

Figure 1-9 Waste pickers in Saudi Arabia in two different examples. Part A: adapted from Alsebaei (2007) and part B: adapted from Albargi (2013)

Koukosia et al. (2013) reported that in 2013, the total generated MSW in Saudi Arabia was 13 Mt. This means that collecting and disposing of each metric ton of waste in Saudi Arabia cost \$161 t^{-1} (GBP 100) in 2013. According to (Hoornweg and Bhada-Tata, 2012), this cost is normal for a high income country for waste collection and landfill use.

Figure 1-10 Cleaning contractors' workers searching in the waste containers for recyclable waste. Adapted from Albargi (2013)

Landfill is the main way to dispose of municipal solid waste (MSW) in all Saudi cities, but in some of the main cities, there are sorting and recycling plants (MOMRA, 2013). Thus, SWM in Saudi Arabia is not similar in all cities and villages but rather depends on the city municipality's judgment and efforts. For instance, Medina City is considered one of the most successful cities in Saudi Arabia in the field of SWM (as anecdotal evidence from officials has suggested) where part of MSW is sorted and recycled.

Other Saudi cities and villages use the landfills or even open dumps to dispose of their solid waste. The design of the landfills is not the same in all Saudi cities as the landfill design depends on the judgment of the head of the municipality in each city or region. As a result, different types of landfill are seen in different cities; some of them are well designed whereas others are considered an open dump. For example, the landfill in Jeddah city (closest city to Makkah) was lined with four layers with a leachate collection system but without a gas collection system (**Figure 1-11**) (Alsebaei, 2007) whereas the Makkah landfill has no lining (there is only a compacted soil in the base layer) and no gas or leachate collection systems (**Figure 1-12**) (Aziz et al., 2007).

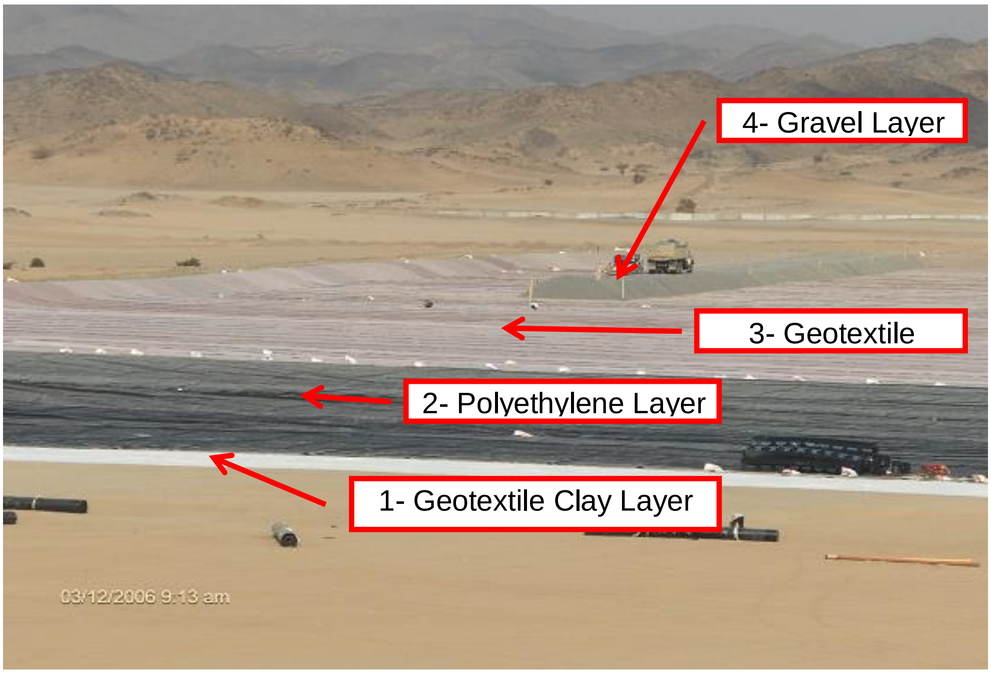

Figure 1-11 Jeddah landfill lining process. Adapted from Alsebaei (2007).

Figure 1-12 Makkah landfill. Adapted from Aziz et al. (2007)

The total quantity of waste generated in Saudi Arabia in 1999 was 8.5 Mt. However, it has been rising dramatically; it reached 10.4 Mt in 2004 (MEP, 2005) and about 13 Mt in 2013 (Koukosia et al., 2013), and is expected to reach 18.4 Mt in 2025 (Hoornweg and Bhada-Tata, 2012). Moreover, the average waste generation rate per person in 2004 was 1.2 kg per day ($kg.d^{-1}$) but it reached 1.5 $kg.d^{-1}$ in the capital city, Riyadh, and 2 $kg.d^{-1}$ during peak months in Makkah city (**Section 1-4**) (MEP, 2005). However, in 2013, the average percentage for all citizens in Saudi Arabia was 1.3 kg per person per day ($kg.p^{-1}.d^{-1}$) (MOMRA, 2013). This average varied between 1.5 $kg.p^{-1}.d^{-1}$ in major cities (Riyadh, Makkah, Medina, Jeddah, Dammam and Al-Ahsa), 1.2 $kg.p^{-1}.d^{-1}$ in medium cities, and 0.8 $kg.p^{-1}.d^{-1}$ in small cities and villages (GCC, 2013).

Due to this quantity of solid waste, in 2003, the Saudi government started to become concerned about the waste problem, which resulted in it publishing a technical manual and guidance for sanitary landfills. This manual includes many regulations for dealing with waste, such as the best way to dispose of the solid waste, how to get benefits from waste, and how to minimize the pollution of air, soil and water, but nothing was mentioned in particular about SWM during the Hajj (MOMRA, 2003). Nowadays, the Saudi waste authority claims that the use of landfill is decreasing and that the percentages of formal and informal recycling and composting are increasing.

However, while the Ministry of Economy and Planning in Saudi Arabia claims that 35% of the total MSW generated in Saudi Arabia is recycled (MEP, 2010), the environmental report of the Cooperation Council for the Arab States of the Gulf stated that the current recycling rate in Saudi Arabia is only 23.5% of the total waste (GCC, 2013). This recycling process mainly occurs in the main Saudi cities such as Riyadh (capital city), Jeddah (second biggest city) and Dammam (MEP, 2010). Some of this recycling occurs in Saudi Arabian factories while the rest is exported to other countries (such as China and India) (Alsebaei, 2007). This is because these recycling facilities (sometimes) focus on recycling the industrial waste, because it is cheaper and cleaner than sorted MSW (Alsebaei, 2007).

In 2011, there were 48 recycling factories in Saudi Arabia (42 of them in the three main cities) (MCI, 2011). These factories were recycling different types of waste or sometimes exporting all the waste components that they sorted in their factory. For instance, the SADACA recycling factory in Jeddah city exports an average of 5000 t of sorted waste every year out of 50,000 t of received mixed waste (SKAB, 2013).

1-6 Waste Management in Makkah City

SWM in Makkah city consists of waste collection, transfer and transport, and disposal in the Makkah landfill (**Figure 1-12**). This system is considered very basic; most of its cost goes to waste collection as it requires a huge number of labourers and significant time and effort especially during the peak months (**Section 2-2-2**).

MSW in Makkah is collected from waste containers (**Figure 1-8**), which are distributed in the streets. This happens three times a day in the central area of Makkah city, twice a day in the main districts and once a day in the rest of Makkah city (RACI, 2008). The collected waste is transported to the transfer stations or to the Makkah landfill by compactor trucks, which have a capacity of $16m^3$ (ibid). There are six transfer stations in Makkah city, each with a capacity of $140m^3$, on two movable containers. The only purpose of these transfer stations is to collect waste from the compactor trucks and transfer it to the landfill in big containers (RACI, 2008).

In terms of waste disposal, although there are six recycling facilities in the western region of Saudi Arabia (five of them in Jeddah city), none of them is located in Makkah city (MCI, 2011). Moreover, there is no composting facility in this region of Saudi Arabia (ibid). Thus, there is no formal waste recycling project in Makkah, and the only way to dispose of waste is by burying it in the Makkah landfill (Makkah Municipality, 2010). This landfill (**Figure 1-12**) is divided into cells; each cell is 75m long, 25m wide and 15m deep and is expected to be filled in just one week (Aziz et al., 2007).

The total quantity of solid waste generated in Makkah every year is unknown because of the waste pickers who collect the recyclable waste from the waste containers in the streets. In 2006, the expected percentage of MSW that had been taken by the waste pickers in Jeddah city (the closest city to Makkah) to be recycled informally was 38% of the total generated waste (Alsebaei, 2007).

However, the weight of the waste generated in Makkah city and disposed of in the Makkah landfill is known, as the waste trucks are weighed at the entrance to the landfill. As unauthorised people are not allowed to enter the Makkah landfill, waste pickers cannot collect waste from the landfill. This means that all the waste that arrives at the landfill is actually buried on it and not taken away. In 2010, this quantity was 690,555 t; 11.14% (76,928 t) of it was generated during the Hajj period (the peak month) (Cleaning Department, 2010).

As mentioned previously, the peaks of the two periods in Makkah are the ninth month (peak of Umrah period) and the twelfth month (Hajj event) of the Islamic calendar (Hijri calendar AH). **Figure 1-13** shows the monthly quantity of solid waste disposed of in the Makkah landfill and the effect of the peak of the two periods. In this figure, it can be seen that the Hajj event has a great effect on the quantity of waste generated because of the huge number of pilgrims. According to Aziz et al. (2007), the generation rate per person in Makkah on normal days is estimated at 1.6 $kg.p^{-1}.d^{-1}$ but during the Hajj and Umrah periods, it increases to 2.05 $kg.p^{-1}.d^{-1}$. Also, as the number of visitors to Makkah increases every year (**Section 1-4**), the quantity of solid waste is raising as well; for instance, between 1996 and 2002, the quantity of solid waste generated in Makkah increased by 46.6% between (RACI, 2008).

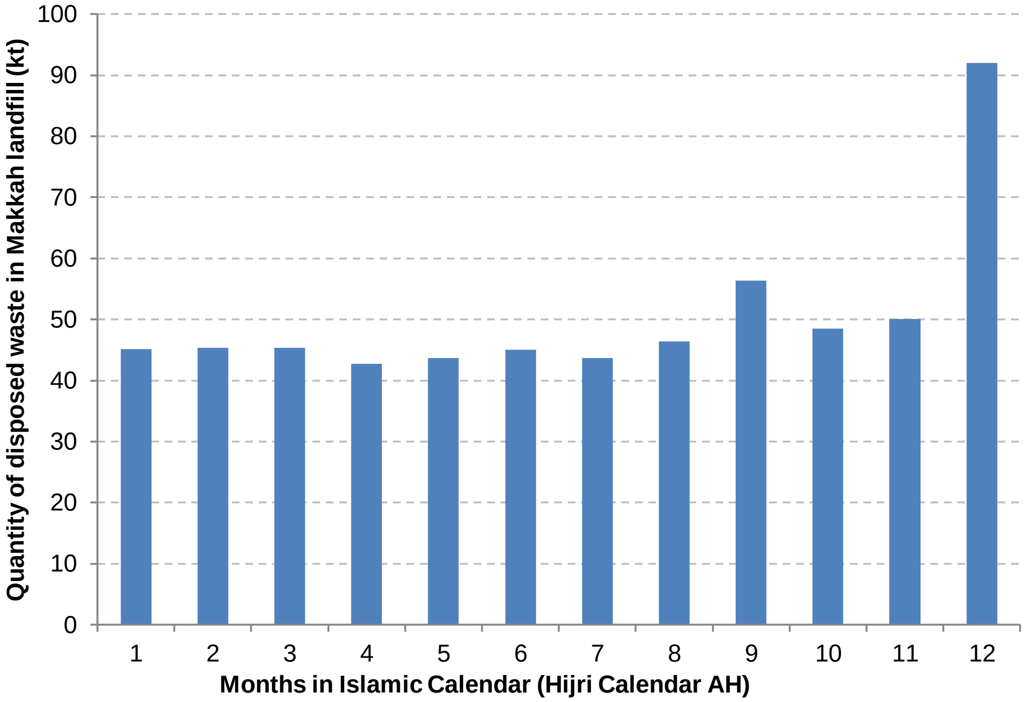

Figure 1-13 The monthly quantity of disposed waste in the Makkah landfill (Cleaning Department, 2010)

The current Makkah cleaning contract, which commenced in 2010, is worth about SAR 7.96 million (approximately GBP 1.33 million). It will last for five years, ending in 2015 (Makkah Municipality, 2010). This contract involves street cleaning, waste collection from street containers, waste transportation, operation of the transfer station, and cleaning the sacred sites during the Hajj. Thus, it can be seen that Makkah Municipality is spending a substantial amount on hiding solid waste but not on protecting the environment or gaining benefits from the waste. However, anecdotal evidence (from officials in the waste authority) suggests that Makkah Municipality is studying the construction of a new well-designed sanitary landfill (beside the old landfill); also, the possibility of constructing sorting and recycling facilities in the same location is being considered.

1-7 Waste Management during the Hajj Event

Although the Saudi government has to undertake many projects in Mina, there are specific projects that take priority, for instance, crowd management, increases in capacity and pilgrims' health care. The problem of solid waste in Mina during the Hajj is not considered to be very important for the government, but it always tries to hide the problem by making the waste less visible. In addition, almost no research has been undertaken, especially regarding the waste in Mina during the Hajj. This means that there is little clarity on the problem for either the government or researchers.

However, Makkah Municipality has tried to implement many solutions to the problems arising from the waste, though this claim is not supported by proper academic research. For example, they distributed more than 1009 compactor boxes in Mina camps and in Mina's streets to store waste in them until the end of the Hajj; 723 of these boxes were allocated to the camps and the rest to Mina's streets (Alsebaei, 2010).

Unfortunately, this project did not succeed as well as the Mina authorities had hoped because the idea was applied without a proper study (ibid). As a result, many camps did not use their boxes because of the waste leachate and odour problems or, in some cases, because there was not enough space in the camp box for all the generated waste (ibid). Thus, less than 35% of these boxes' capacity was used in Hajj 2010 (Cleaning

Department, 2010). Furthermore, the quantity of waste collected in these 1009 boxes was 2824 t, which represented 16.6% of the total waste collected from Mina (17,052 t) (ibid).

Every year, Makkah Municipality makes what they believe will be a good plan for SWM during the Hajj, especially in Mina, but, usually, unexpected problems occur (Alsebaei, 2010). For instance, in Hajj 2010, a major problem was caused by the lack of cleaning workers. This occurred because many of the seasonal workers' visas were sold illegally to other people (about 2121 visas out of 4000) (Garsan, 2011). Thus, Makkah Municipality fined the cleaning contractor about SR 21 million (approximately GBP 3.5 million) (ibid).

In 2010, the total quantity of solid waste generated during five days in Mina and disposed of in the landfill was 17,052 t (Cleaning Department, 2010). As mentioned previously, the total quantity of domestic solid waste disposed of in the Makkah landfill in the twelfth month of the Islamic calendar (Hajj period) in 2010 was 76,928 t (Cleaning Department, 2010). This means that 22.1% of the waste disposed of in the landfill that month was generated in Mina during only five days, which represents just how big the problem is. Almost every year, this number rises because of the huge projects that aim to increase the capacity of Mina which lead to an increase in the number of pilgrims. **Figure 1-14** shows the total quantity of solid waste disposed of in the Makkah landfill from Mina (generated in five days) over six years (Cleaning Department, 2010).

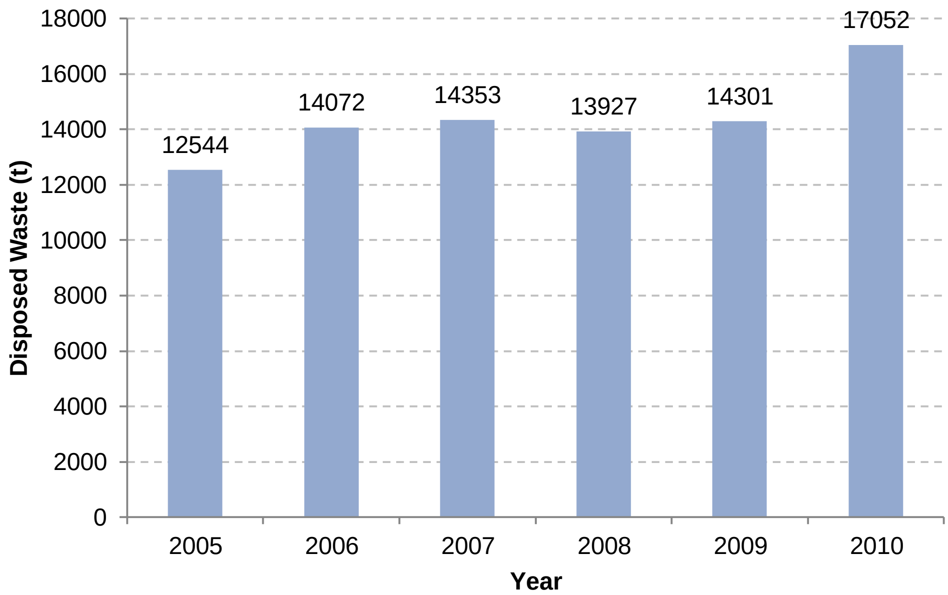

Figure 1-14 The total quantity of solid waste disposed of in the Makkah landfill from Mina during six years (Cleaning Department, 2010)

It is expected that all these quantities of generated waste in Mina are transferred to the landfill. On-site observations revealed there were a small number of waste pickers in Mina after the end of the event (while the cleaning workers were collecting the waste). However, these waste pickers were not looking for recyclable waste but were searching for valuables that pilgrims might have lost (such as money, mobile phones and jewellery). Thus, it is assumed that there is no formal or informal recycling in Mina.

However, if the quantity of generated waste in Mina is assumed to be the same as the quantity of waste disposed of in Makkah landfill, then, on average, pilgrims generated 3410.4 t a day in the 4.8 km^2 area (0.71 $kg.m^{-2}$ of waste per day). This means that the waste generation rate per pilgrim was 4.62 $kg.p^{-1}$ (0.92 $kg.p^{-1}.d^{-1}$). However, SWM in Mina is divided into two parts (based on the on-site observations): the streets (waste managed by Makkah Municipality) and Mina camps (waste managed by the camp managers) as shown in **Figure 1-15**.

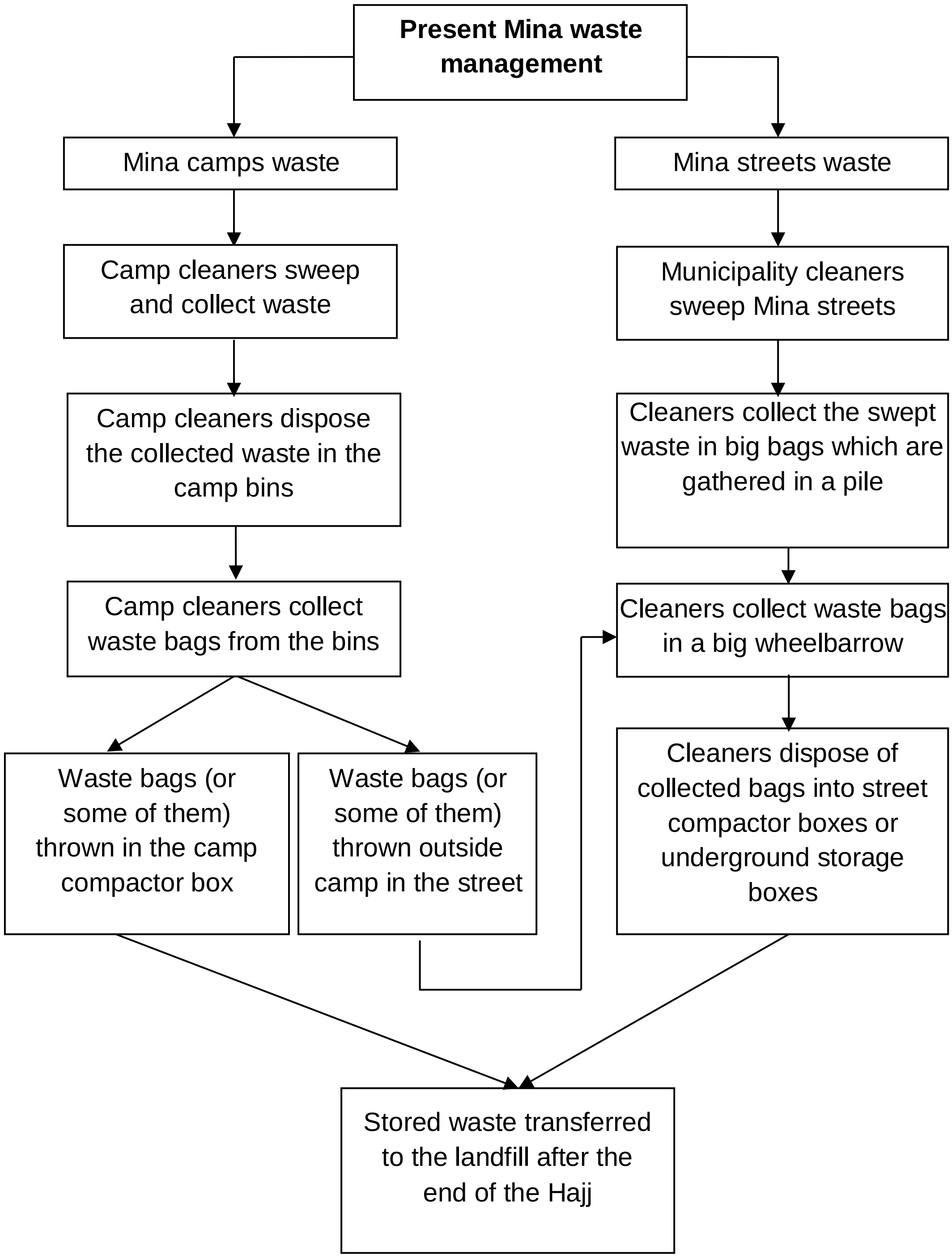

Figure 1-15 Solid waste management in Mina, based on the researcher's observation

1-7-1 Solid Waste Management in Mina Streets

The management of solid waste in Mina's streets consists of waste generation, collection, storage, transfer, and disposal. There are many sources for the solid waste generated in Mina's streets; these can be summarized as follows (according to the researcher's observation):

- Pilgrims throw their waste on to the street while they are walking, as they usually find it very difficult to reach the waste bins at the edge of the street (due to the crowds).
- Illegal pilgrims, who stay and sleep on the sidewalks of the streets because they are not booked into any of Mina camps, throw their waste onto the streets (**Figure 1-16**).

Figure 1-16 Illegal pilgrims throw their waste onto the streets

- Many camps cleaners dispose of camp waste in the street (**Figure 1-17**). This is because they prefer not to use their compactor boxes because of the problems associated with them or because they are full or broken (even though there are special teams in Mina to fix them as soon as possible).

Figure 1-17 Camp cleaning workers dispose of their camp waste on street

- Charity donations in the form of food and drinks cause a huge amount of waste in Mina's streets (**Figure 1-18**)

Figure 1-18 Waste caused by charity donations in Mina's streets

- The street compactor boxes are full (**Figure 1-19**).

Figure 1-19 Street compactor box is full and the waste piled around it

- Food shops and other small shops generate a huge quantity of waste (**Figure 1-20**).

Figure 1-20 A fruit shop and the waste resulting from it

As was observed during the field work, after waste starts to accumulate in Mina streets, specific numbers of cleaners in each street start to sweep and collect waste in big bags, which are disposed of in the street compactor boxes and the underground storage boxes (129 boxes). Generally, these workers are divided into groups, each group being responsible for a certain street or part of it. Finally, after the end of the event, the municipality transfers these boxes to the landfill. After being emptied and washed, they are stored for the next year.

1-7-2 Solid Waste Management in Mina Camps

SWM inside the camps is not the same for all camps because it depends on the attitude and behaviour of the camps managers as well as the camp cleaners. Although any camp manager who disposes of camp waste on the street is fined SR10,000 (approximately GBP1,666) (Alsebaei, 2010), many camp managers threw their waste outside the compactor box and onto the street (as was observed, **Figure 1-17**). As the researcher observed, there are many reasons for that:

- The compactor box produces waste leachate (**Figure 1-21**) and foul odours.
- The compactor box is broken or full.
- The camp cleaners do not know how to use the compactor boxes, although there is an annual compulsory training programme on how to operate the compactor boxes (run by Makkah Municipality)
- Sometimes, the camp cleaners accumulate the collected waste bags in the compactor box room during the day and, at night, when they try to compact the waste inside the

box, they cannot as the waste bags prevent them from reaching the buttons (**Figure 1-22**).

Figure 1-21 Waste leachate resulting from camp compactor box

Figure 1-22 Compactor box is buried under the waste pile, which prevent the access to the switches

CHAPTER 2

LITERATURE REVIEW

2-1 Municipal Solid Waste (MSW)

2-1-1 Waste Definition and Types

Waste can be defined as material that its owner no longer wants (Visvanathan et al., 2006a). Indeed, the EC Waste Framework Directive 2008/98/EC defines waste as "*any substance or object which the holder discards or intends or is required to discard*" (EU Commission, 2008). McDougall et al. (2008) categorised waste into six different groups: physical condition (solid, liquid and gas), the original usage, physical properties (compostable, recyclable and combustible), materials (plastic, paper, etc.), safety (hazardous and non-hazardous), and source of the waste generation. Furthermore, Christensen (2011) divided waste into four main categories according to its source: domestic waste, commercial and institutional waste, industrial waste, and construction and demolition waste.

2-1-2 Municipal Solid Waste: Definition and Types

Municipal solid waste (MSW) usually consists of three types of waste: domestic waste, municipal services' waste, and institutional waste. Domestic waste includes household waste, household hazardous waste, household bulk waste, and garden waste (Christensen, 2011) while Strange (2002) defined municipal waste (based on the British understanding) as the waste that the local authorities collect directly or indirectly, and this includes the following types of waste: household waste, household hazardous waste, household bulk waste, street litter, garden waste, and office waste.

1- *Household waste:* household waste is waste that comes from residential facilities, such as houses, apartment complexes, and hotels, and which contains mainly food residuals (organic), paper and cardboard, plastic, metals, textiles, wood, and glass (Vaughn, 2009). This kind of waste is usually divided into two types according to its content: organic and non-organic waste (Cheremisinoff, 2003). This division helps identify the method for safe disposal of the waste, such as composting for organic and recycling for the others (if recyclable).
2- *Household hazardous waste*: this is defined as waste that contains any material that has been classified by the US Environmental Protection Agency (EPA) as hazardous based on the following four characteristics: ignitability, reactivity, corrosivity, or toxicity (Vaughn, 2009). For instance, solvents, oils, paints, and batteries are considered as household hazardous wastes (Christensen, 2011). Cheremisinoff (2003) reported that one of the most important problems in domestic waste is that it usually contains hazardous waste that is being disposed of with household wastes.
3- *Household bulk waste:* this type of waste usually comes from houses, such as old furniture, large electrical appliances and other items that weigh more than 25 kilogram (Ockwell, 2012).
4- *Street litter*: this kind of waste is generally generated in the streets or highways by careless consumers who dispose of it outside the street waste bins or waste collection containers (Cheremisinoff, 2003). Street litter usually contains glass, plastic, paper, metals, textiles, food and cigarette butts (Arafat et al., 2007).

5- *Garden waste* (green waste): this comes from the maintenance process of domestic gardens and municipal parks. It contains both organic waste (grass, leaves and timber) and inorganic waste (soil and gravel) (Boldrin and Christensen, 2010).

6- *Office waste*: this type of waste comes from work places, such as business establishments, institutions (schools, hospitals and governmental centres), and other offices (Boldrin and Christensen, 2010). It consists mainly of paper and cardboard, plastic, wood, food waste, glass, metals and hazardous waste (Vaughn, 2009).

2 -2 Municipal Solid Waste Management (MSWM)

The term "municipal solid waste management" (MSWM) can be defined as the methodological management of six activities with consideration for public health, the environment, aesthetics, and the economy. These activities are waste generation, storage, collection, transportation, treatment, and disposal (Al-Maaded et al., 2012). Usually, collection and transportation are the most expensive activities in the process whereas treatment and disposal have the greatest effect on the environment (Vaughn, 2009). However, Cheremisinoff (2003) believed that waste disposal is the most important problem facing many countries. Thus, EPA found four different strategies to control the disposal of the MSW: recycling and composting, combustion, waste minimization, and landfill (ibid).

2-2-1 Solid Waste Generation and Sorting at Source (Source Separation)

Jayasinghe et al. (2013) reported that solid waste generation depends on the life-style, culture, level of industrialization in the country, individuals' socio-economic level, and climatic conditions. In addition, Visvanathan et al. (2006a) suggested that the increase in waste generation is due to further factors, namely, population growth, rapid urbanization, higher incomes leading to changes in life-style, consumption of more processed foods, and neo-industrialization.

It is believed that to achieve the best method of managing MSW, waste generation should be controlled (Zhuang et al., 2008). One important and critical element of this process is waste source separation by waste generators. Waste sorting at source (source separation) is defined as the segregation of recyclable materials (such as plastic, paper, glass, and metals) from the rest of the waste at the point of generation (Tchobanoglous, 2003). Sorting at source is considered as one of the most important factors in reducing the cost and energy of the production process and increasing the efficiency and the quality of waste recycling process by keeping the recyclable materials uncontaminated by other waste (Murray, 1999; Velis et al., 2012). To make this happen, waste should be sorted (at least) into wet organic waste and dry inorganic waste (Velis et al., 2012).

The sorting at source system should be designed according many different factors, and these depend generally on time and place. Nowadays, many of the developed countries consider this process one of the citizens' responsibilities. However, the method of waste separation at source differs between countries and sometimes between cities in the same country. The easiest and most basic method is to sort the waste into two groups, namely, recyclable waste and the rest (includes organic waste), while there are other systems, such as in Germany, which divide the household waste into five groups or more (Jaron et al., 2006). Christensen (2011) reported that the method used for waste sorting at source affects the whole process of recycling and the equipment needed for it, and to increase the rate of sorting, the household should be motivated to sort their waste effectively.

However, the waste sorting process can occur at various places (if it is not done completely at source), for example, transfer stations, material recovery facilities (MRFs) and the landfill (Alsebaei, 2007). Moreover, there is another method by which waste can be sorted: sorting by waste pickers (informal recycling). These are people who look for recyclable material in the waste disposal sites (Wachukwu et al., 2010).

To sum up, Christensen (2011) reported that the best method of waste sorting is separation at source because its cost is very low and the recyclable material will be uncontaminated by the rest of the waste, whereas the sorting of waste in other places is expensive and some of the recovered material (such as paper and cardboard) will be contaminated, which make it unsuitable for recycling. In addition, Zhuang et al. (2008) found that the solid waste source separation is a cost effective system (if the SWM system is well designed).

2-2-2 Solid Waste Collection

Eisted et al. (2009) defined MSW collection as the action of collecting waste by using a specific route in a specific area until the truck is full or until the end of the route. The collection frequency is also determined according to the waste generation rate and manner. For instance, in the UK (developed country), waste trucks collect the mixed waste once a week whereas in Saudi Arabia (developing country) they collect the waste once or twice a day (Alsebaei, 2007).

Gardia et al. (2006) reported that the cost of the collection process varies between 50% and 70% of the total cost of SWM in developed countries whereas in developing countries, it can reach 70% to 90% of the total cost, depending on the collection and disposal procedures. Williams (2005) explained that the reason for the high cost of the waste collection is the need for huge numbers of labourers and the immense effort required in this process.

2-2-3 Solid Waste Transportation

When the waste collection is completed, the loaded trucks move to a specific place to unload the waste. This procedure is called waste transport (Eisted et al., 2009). The waste transport is a costly and time-consuming process because treatment and disposal places usually are located far from the city (Tchobanoglous, 2003). To minimise the number of long trips taken by the waste trucks to the unloading point, the trucks can dispose of the collected waste at collection points called transfer stations, where waste is compacted and transferred into big containers with volumes varying between 7.5 m^3 and 26.7 m^3. Then, it is transferred by a truck trailer to the treatment or disposal location (Mihelcic and Auer, 1999; USEPA, 2002b).

2-2-4 Solid Waste Treatment and Disposal

There are many methods for disposing of or treating MSW. Some of them pollute the environment and are very costly without offering any financial returns while others cause less pollution (or none) and have financial benefits. Pichtel (2005) summarised the treatment (resource recovery) and disposal methods as follows: sanitary landfills and open dumps; incineration with and without energy recovery; composting; and reduce, reuse, recycle (the 3 Rs).

<u>*Sanitary landfills and open dumps*</u>

Landfills are the most common form of waste disposal, especially in developing countries. Nonetheless, while many developed countries are trying to avoid using landfills, there are many others still using this method of waste disposal, even though in lower percentages. For instance, in 2012-2013, the UK's local authorities disposed of 34% of generated MSW in landfills (DEFRA, 2013).

However, many countries still use open dumps as a form of landfill, as can be seen in the small cities in Saudi Arabia (Alsebaei, 2007). "Open dump" is a site where waste is disposed of in a disorderly fashion without regard for the environment (Ghazali et al., 2014). In contrast, sanitary landfill is defined as the method of waste disposal on land, which does not pollute the environment or affect public health and safety, as waste is spread, compacted, and covered by soil daily (Ghazali et al., 2014).

A sanitary landfill consists of many cells, which should be designed at specific slopes. These cells usually contain a liner of different materials, a leachate collection system, and a gas collection system. German waste disposal regulations classify landfills into five categories according to the waste content, as follows (Visvanathan et al., 2006a): class 0 is designed especially for inert waste, class I is for quite inert municipal waste, class II is for municipal waste, class III deals with hazardous waste, and class IV is designed for underground disposal. The main differences between these categories are in the site selection, gas and leachate collection systems, and lining system.

In the landfill, the biodegradable waste causes gases to rise; these are collected by a gas collection system. These gases typically consist of methane (63.8%), carbon dioxide (33.6%), nitrogen (2.4%), and a small percentage of a wide range of other gases (Williams, 2005). In special facilities, these gases can be used to create energy.

Landfills can have a negative impact on the environment and on the economy and socially. Pellaumail (2001) identified some of these impacts as follows: exacerbating the problem of climate change, polluting the surrounding environment, sending emissions into the air, contaminating ground water and land, and destroying valuable resources, which leads to the increased consumption of raw materials.

2-2-5 Resource Recovery

Resource recovery (where energy and materials are recovered) can be done through: waste incineration (with energy recovery), biological treatment, and recycling (Eriksson et al., 2005).

Incineration with energy recovery

Incineration refers to the reduction of the volume of waste in a specially designed facility by a combustion process, with or without heat recovery, in order to create power (Tchobanoglous, 2003). This process produces hot gases, such as nitrogen, carbon dioxide, and water vapour, where energy can be formed by heat exchange.

There are many advantages to using incinerators that generate energy from waste; these include control of air emissions, reduction of the volume of waste by 90%, and no methane production in the process (Cybulska et al., 2000). Thus, many developed countries use waste incineration with energy recovery as one method to dispose of household waste. For instance, 22% of UK waste went for incineration in 2012 (DEFRA, 2013).

On the other hand, this process does not destroy all the hazardous materials and heavy metals in the waste, which will be dumped in the landfill with the ash. In addition, incineration is considered a waste of resources because some of the incinerated waste could be recycled or composted. Thus, UK's Friends of the Earth organization opposes incineration for many reasons. These include the following (Pellaumail, 2001):

- There is a waste of resources as 80% of the UK's recyclable and compostable solid waste is incinerated.
- The ash has to be dumped in the landfill, which will produce emissions.
- The recycling industry offers far more jobs than the incineration industry.
- Incineration is a very costly process; the recycling process costs far less.
- It is an eyesore, and it produces more noise and traffic than recycling does.

Composting and anaerobic digestion

Composting is considered to be a form of recycling and can be defined as the degradation of the organic content of solid waste by bacteria, fungi, insects, and animals in the presence of an air supply (Visvanathan et al., 2006a). Moreover, compost is used to improve soil fertility (Cybulska et al., 2000). Another benefit to be gained from organic waste is that of anaerobic digestion. This is a method of making compost using airtight containers where bacteria break down the biodegradable material in the absence of oxygen (ibid). This process produces energy-rich biogas, which mainly consists of carbon dioxide and methane and which is used to generate electricity (Holm-Nielsen and AlSeadi, 2004).

However, the main disadvantages of producing compost are the accompanying odours and spores and the leachate (Cybulska et al., 2000). In addition, there will be no benefit from compost if it is produced in a non-agricultural city or country because the transportation will significantly increase the total cost.

Reduce, Reuse, Recycle (3 Rs)

The main aim of 3 Rs is to minimize waste; thus, waste minimization involves waste prevention and treatment (Singh et al., 2014). Firstly, waste reduction (waste prevention) focuses on minimising the amount of waste produced, for instance, reducing packaging materials or their thickness, which would decrease the total weight (Williams, 2005). Such a project is sometimes supported by the government with the aim of controlling waste generation. For instance, in 2012, Germany started a resource efficiency programme (ProgRess); this included a waste prevention programme, which focuses on preventing substances, materials, or products from becoming waste (BMU, 2013b).

Secondly, waste reuse focuses on how products can be reusable instead of disposable (USEPA, 2014b). For instance, buying used products and renting or borrowing are considered as the reuse of products (USEPA, 2014b). Another example would be the reuse of plastic carrier bags or glass bottles (Williams, 2005). Waste reuse is also considered as one form of waste prevention where the life span of the products is increased (Singh et al., 2014).

Finally, recycling is defined as the process of recovering material resources, where waste is first collected and then processed, and finally, the end product of this process is a raw material that can be used to manufacture new products (USEPA, 2014b). Waste recycling can be done with organic waste, which will produce compost, and with inorganic waste, which will produce raw materials. According to Velis and Brunner (2013), the main benefit of waste recycling is to protect the environment by decreasing the energy consumption, reducing the usage of raw material and the need for mining, and control the emissions. In addition, the recycling industry can potentially create new job opportunities. For instance, in Germany in 2013, there were about 200,000 employees working in 3,000 companies; these companies achieved about 40 billion euro profits from recycling and recovering resources from waste (BMU, 2013a).

The economic benefit of the recycling process depends mainly on waste sorting at source. This means that separation at the point of waste generation is much more efficient than separation in the sorting facility (**Section 2-2-1**). Moreover, the success of recycling depends largely on educating the public (**Section 2-3**). However, Christensen (2011) stated that people may have high intention to sort their waste as a part of their environmental awareness and responsibility, but many studies have shown that in order to develop successful recycling programmes, governments should make such programmes compulsory (Fisher, 2006; FOE, 2008)

Waste hierarchy

All the previous methods of waste recovery (prevention, reuse and recycling) or waste disposal (landfill) formulate a waste management hierarchy, which has been used in western countries and parts of Asia since the 1980s as the main method to manage waste (Christensen, 2011). The waste hierarchy ranks the different options of waste management based on how environmentally friendly they are, as shown in **Figure 2-1** (DEFRA, 2011). According to Christensen (2011), minimising or avoiding the use of landfill is the main goal of waste hierarchy.

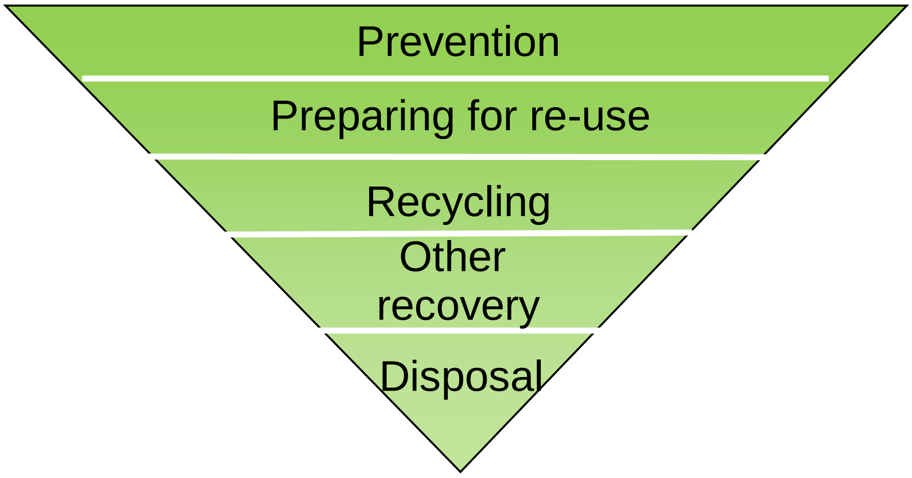

Figure 2-1 Waste hierarchy. Adapted from DEFRA (2011)

2-2-6 Types of Recycling Systems

Waste recycling can be done formally or informally, with one main difference being the recyclable waste collection method. According to Suchada et al. (2003), formal recycling is done through registered enterprises with an official licence from the local government whereas the informal recycling system is performed by the informal recycling sector (IRS), that is, individuals or enterprises who are not authorised by the official waste authority. Informal recycling usually takes place in developing countries as the main method to collect recyclable waste, which is usually done by waste pickers (**Section 2-5**), even though in these countries, formal recycling systems can also be found (Wilson et al., 2006).

Informal recycling is becoming an increasingly important part of SWM especially in low middle income developing countries; indeed, this type of recycling treats about 20 – 30% of the total generated waste in these countries (Velis et al., 2012). Although this type of recycling generates many problems (such as public health, safety, and pollution), it lowers the cost of waste collection and disposal (Wilson et al., 2006; Velis et al., 2012).

On the other hand, in developed high-income countries, formal recycling seems to be the main method of waste recovery. There are many methods to collect recyclable waste formally, but generally, the waste is sorted at source before being collected. Some of the main recycling collection methods are door-to-door schemes, kerbside collection systems, drop-off centres (with or without buy-back), and street container collection systems (Williams, 2005). In these methods, recyclable materials can be collected either mixed together (single stream) or separate from each other (**Section 2-2-1**).

2-3 Factors Affecting Recycling Rate and Waste Sorting Behaviour

The main factor affecting the recycling performance is the sorting attitude and behaviour of the waste generators. Perrin (2002) found that the existence of a positive environment means better sorting behaviour, which will lead to an increase in the recycling rate. Moreover, the recycling process depends on four major categories: the individual, the material, system design, and scheme maintenance (Perrin, 2002). There is an interference effect between these factors; for instance, a system design that is inconvenient for the individual results in a decrease in the sorted waste percentage, which in turn, will reduce the recycling rate. However, Perrin (2002) concluded that the material is the most important factor affecting sorting percentages, followed by the maintenance plan and design and finally, the individuals. Thus, it is critical to design an appropriate recycling system that should mainly consider what type of source sorting procedure (**section 2-2-1**) is the most suitable (Harder et al., 2006). This means that the recycling system should be designed based on the factors that affect these four categories. These factors will affect mainly individuals' willingness to sort their waste. For instance, people tend to sort their easy waste, such as the newspapers and magazines, whereas it is unlikely that they will sort the food containers (Perrin, 2002).

2-3-1 Recycling System Design

<u>*The plan*</u>

According to Hogg and Mansell (2002), in order to improve the recycling rate or set up a new system, the authorities responsible for waste management may need to adjust their plans and policies. The new policy and plan should consider other waste management plans in developed countries that have already achieved a high recycling rate (ibid). Moreover, to achieve a high percentage of sorted waste at source, the type of waste that is easiest to sort and more available should be selected to be separated at source (Barton et al., 2001).

To design a practical recycling system, a full background about the current SWM should be obtained. This should be followed by a good plan for this system being developed in collaboration with all planning authorities to achieve the following (DCLG, 2011):

- converting the waste to be a resource and make the disposal is the last choice;
- involving the communities in their own waste management;
- creating and implementing a national waste and recycling strategy;
- protecting both human health and the environment when the waste is recovered or disposed of;
- studying the requirements of the system for all participants;

- providing more green areas; and
- considering the sustainability of SWM in designing the new developments.

However, the design of a good recycling system mainly depends on the area where the system is placed. Furthermore, the system should designed to be convenient, simple, and easy to use, which will maximize the sorted waste rate (Barton et al., 2001)

Recycling bins design

Storage systems should be easy to handle to increase the source separation (Pieters and Verhallen, 1986). Schultz et al. (1995) identified two methods to sort household solid waste: segregation of all recyclable materials together in one sorting bin or sorted recyclable materials in numerous containers (**Section 2-2-1**). These containers should be designed in a way that facilitates and controls the waste separation process. As reported by DEFRA (2008), a small barrier should be placed in the top of the recycling bin to reduce contamination. This barrier should be designed according to certain specifications to make the disposal of the sorted waste easy while it should prevent or reduce the disposal of other waste in the sorting bins. For example, the plastic and cans sorting bins should have a circular shaped waste opening (ibid). However, a certain level of contamination is expected in the sorting bins; DEFRA (2008) estimated the accepted level of contamination to be between 5% - 20%.

One of the most important aspects in the design of recycling bins is to explain clearly to people the kind of waste they have to sort into the bins (**Section 2-3-4**). This is the main reason for the use of iconography. DEFRA (2008) stated that the use of iconography will make the sorting process easier as it will make the consumers more confident and accurate when they sort their waste while WRAP (2012) reported that iconography is a very important tool because it raises the willingness to sort, provides instructions and information, and increases awareness and knowledge.

Sorting bins location

DEFRA (2008) reported that sorting bins should be located in the busy areas but should avoid blocking the entrances and causing problems in crowded places. In addition, the recycling bins should be located at the spot of waste generation (ibid). For instance, at big events, these bins should be found near the refreshments and close to the vending machines especially that sell juices and water bottles. Furthermore, it is recommended that recycling bins be distributed beside the general waste bins to avoid contamination of the recyclable waste (ibid).

2-3-2 Recycling Material

The recycling system should consider the types of waste generated in the area and which waste items can be sorted at source (DEFRA, 2008). This means that the sorted waste should represent the main waste components in that area. However, the recycling system in the busy areas should collect fewer materials than other areas (ibid). This is because in busy areas, people should be asked to sort the main items in their waste whereas in other places, they might be asked to sort more items.

Many materials in household waste can be potentially recycled. The most important recyclable materials in household waste are plastic, paper and cardboard, metals, and glass (Williams, 2005). Of these materials, aluminium cans is considered the most profitable material to recycle, because it exists in abundance in household waste and because recycling aluminium is much cheaper and consumes less energy than producing it from raw materials (Calcott and Walls, 2005). Furthermore, while recycling plastic might lower its quality, it protects the environment from non-degradable waste and results in lower oil consumption, which is the raw material of plastic (Ross and Evans, 2003).

2-3-3 Recycling Scheme Maintenance

According to Perrin (2002), recycling maintenance schemes should include participants' feedback, level of understanding, and communication and education about the system. These can be achieved through monitoring and assessment of the recycling system and participants.

Monitoring can be defined as the method of measuring the effects or the schemes of the provided service whereas the assessment or evaluation means drawing results from the data obtained from the monitoring (WRAP, 2010). This means that every system should be monitored and assessed by the authorities to identify the performance of the provided services. Moreover, in any kind of services, it is very important to decide what and whom to monitor. Therefore, the monitoring and evaluation of any activity should concentrate on the activity's aim and objectives and what it was expected to accomplish (WRAP, 2010).

2-3-4 Individuals

To set-up a successful recycling system, individuals' behaviour should be monitored and improved (through educational programmes and information campaigns) (Nixon and Saphores, 2009). These campaigns must provide enough information about the recycling system and the individuals' roles. Kok and Siero (1985) reported that individuals will participate in a source separation project if they

- have enough information about it.
- understand what Involved on it
- have a positive attitude towards it
- have the ability to do it
- accept the responsibility (if this increases, the level of sorted waste will increase) (Kok and Siero, 1985; Thogersen, 1994; Ouellette and Wood, 1998; Knussen and Yule, 2008; Miafodzyeva et al., 2010)
- have environmental knowledge especially recycling issue
- are aware of consequences.

Furthermore, Thogersen (1994) added three more determinants to the previous factors: motivation to sort (such as motivating the participants by pointing out the public benefits), ability to convert intention to behaviour, and opportunity. Moreover, gaining benefits from waste source separation motivates people and increases their intention to sort their waste more. Pieters and Verhallen (1986) explained that both the motivation and the ability to sort waste play important roles in participants' behaviour regarding source separation. Therefore, people should be motivated to participate in source separation projects through very well designed publicity campaigns (Ekere et al., 2009).

Pieters and Verhallen (1986) obtained that there was a positive relationship between individuals' waste source separation and their level of education and income. This means when the level of education and income increase in the household, the percentage of sorted waste rises. However, while Schultz et al. (1995) stated that the relation between high income and source separation to be positive, they found no significant relation between sorting and gender or age.

On the other hand, Kok and Siero (1985) suggested that the level of education and income do not affect the intention to sort, but age does (older people have more positive intentions to sort). In addition, Nixon and Saphores (2009) confirmed that there is a significant relation between participating in a recycling system and age as well as ethnicity, but not level of education and income. This variation in the relationship between participating in a sorting project and other factors is dependent on the time and place (Schultz et al., 1995).

Gonzalez-Torre and Adenso-Diaz (2005) suggested that the factors that affect source separation projects vary in each community. For instance, in Minsk city, Belarus, the factors that affected the level of sorting positively were a high level of education, a high social level, and older age, while the factors that affected the Ugandan source separation project were gender, the location of the household, the community and the social influence and pressure (Ekere et al., 2009).

Miafodzyeva and Brandt (2013) summarized the findings of studies between 1990 and 2010 on the subject household recycling behaviour and reported the following findings:

1- The most important factor controlling the household individuals' behaviour is the convenience of the sorting system, which may lead the public to accept and participate in the source separation project.

2- The householders need a new, smart, and convenient source separation system (especially in developed societies), which should be considered in the plan.

3- Households' behaviour can be improved by increasing the public knowledge about recycling and creating a pleasant and useful image about recycling and its importance.

4- Information should be provided to the public about source separation and recycling (by promotion and publicity) as the public's environmental concern plays an important role in their decision to sort waste.

5- Other less important factors affecting the sorting behaviour are effort, access to the recycling facilities, social level, and income.

6- The relation between sorting behaviour and socio-demographic is poor.

Waste sorting intention and behaviour

Time is needed for a new method to handle solid waste (especially source separation) to be acquired, understood, and performed and this might explain the variance between intentions and behaviour (Thogersen, 1994). However, people who participate in the beginning of a sorting project might show decreasing accuracy with the passage of time (Kok and Siero, 1985). Intentions can differ from real behaviours because of difficulties in participation. Kok and Siero (1985) identified these difficulties:

- bringing the sorted waste to the separation bin
- the distance to the bin.
- cleaning the sorted waste (i.e. from food residual)
- remembering to sort waste
- needing space at home for the sorting bins

- the presence of sharp objects in the waste
- the amount of time required for the process (sometimes not significant)

Nixon and Saphores (2009) identified additional factors:

- failure of the educational programmes and information campaigns
- the presence of a great diversity in ethnicity
- social interactions
- human emotions

However, all of the previous factors can be considered as general factors, and they might not all be applicable in some cases, or there might be additional factors. For instance, (Miafodzyeva et al., 2010) concluded that in Minsk city, the factors that made citizens change their intention to sort their household waste (negative effect) were the time, effort, and space required and the difficulty of transporting the waste from the household; while in the Spinach case (northern region), the factors which had negative effects were the distance to the sorting bins and the limited storage area for the sorted waste, whereas easier access to the recycling bins increased the sorting rate (Gonzalez-Torre and Adenso-Diaz, 2005).

It is believed that there is sometimes a significant relationship between behaviour and intention. For instance, Ittiravivongs (2012) reported that in Thai households, the sorting behaviour was considerably predicted by their intentions to recycle, but this strong relation depends on the presence of a recycling habit; with a higher level of recycling habit, the relationship between the intention and behaviour becomes stronger (Knussen and Yule, 2008; Ittiravivongs, 2012). This means a high waste source separation habit will possibly motivate most people who have the intention to recycle to convert their intention into an actual behaviour. However, the lack of this habit may cause people to dispose of their recyclable waste with their MSW, which is where the big difference between intention and behaviour appears (Knussen and Yule, 2008).

Based on the previous statement, it can be said that the individuals' source separation process consists of two elements: intention to sort and actual sorting behaviour. Thus, it is important to identify generally the factors that affect individuals' intentions and behaviours.

Based on the theory of planned behaviour (TPB), there are three main determinants for people's intentions (Ajzen, 2005):

1- personality, which represents the individual's *attitude toward the behaviour*
2- the impact of the society (*subjective norm*)
3- self-ability and efficiency to implement the behaviour *(perceived behavioural control*).

If these three determinants are positive towards waste sorting, then the intention to separate the waste at source will increase (Ioannou et al., 2013). However, individuals usually perform a behaviour when (Ajzen, 2005) they have a positive evaluation to it, they are under a social pressure, and they have the resources and opportunity to do so.

Based on this, Ajzen (2005) developed a graphical relationship for the TPB. Ioannou et al. (2013) formed an extended TPB by adding more indicators about demographic and recycling conditions to the behavioural intention (**Figure 2-2**), as they claimed that the extended TPB makes this theory more suitable to be used for waste sorting and recycling intention and behaviour.

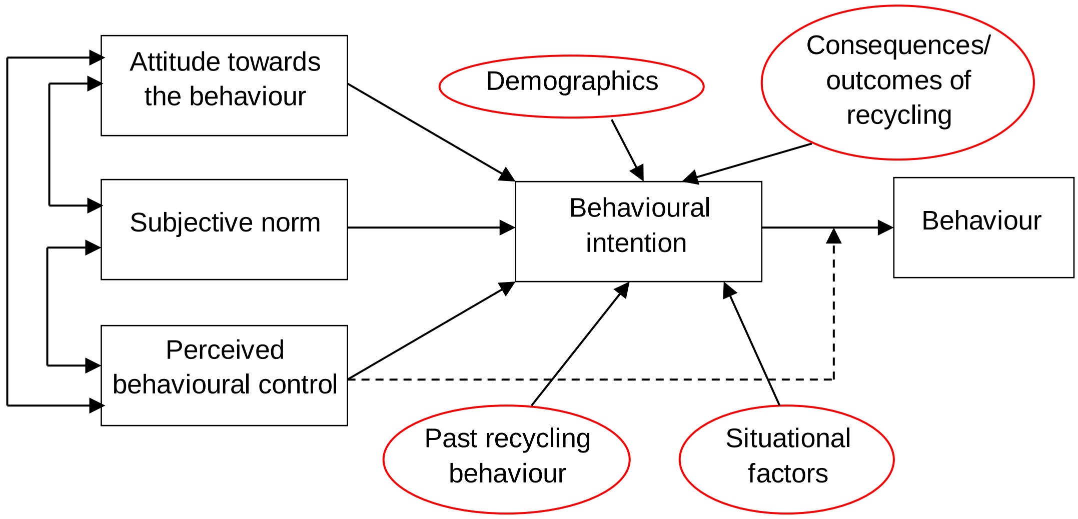

Figure 2-2 The extended theory of planned behaviour. Adapted from Ioannou et al. (2013)

Some of the factors that affect the intention and behaviour stages might be similar. This means that sometimes the same factor can change the intention at the beginning or can change the actual behaviour of source separation.

2-4 Integrated Sustainable Waste Management ISWM

Integrated sustainable waste management (ISWM) is used to assess three important aspects of waste management: stakeholders (people who participate in managing the waste even informally), the physical elements of waste management, and sustainability aspects (including environment, decision makers, waste management institutions, culture and society, economic, and performance) (van de Klundert and Anschütz, 2001). Consequently, this method should be used by decision makers as a tool to assess SWM. In 2010, the ISWM system was used to assess SWM systems in 20 cities around the world and the findings were published in UN-Habitat's '*Solid Waste Management in the World's Cities*' (Scheinberg A et al., 2010). This framework was developed later by some of the main authors of this book in two different papers and a user manual (Wilson et al., 2013a; Wilson et al., 2013b; Wilson et al., 2015). **Figure 2-3** shows the developed ISWM framework (which is called Wasteaware ISWM benchmark indicators) where it was divided into two parts: physical components and governance aspects. The physical components include waste collection, disposal, and recycling, whereas the governance aspects cover inclusivity, financial sustainability, sound institutions, and proactive policies (**Figure 2-3**) (Wilson et al., 2015). Furthermore, each of the previous six elements consists of number of different indicators, and each indicator is derived from certain criteria (**Section 4-6**). Wilson et al. (2013a) concluded that a successful SWM system needs an effective management of both its physical elements and its governance aspects.

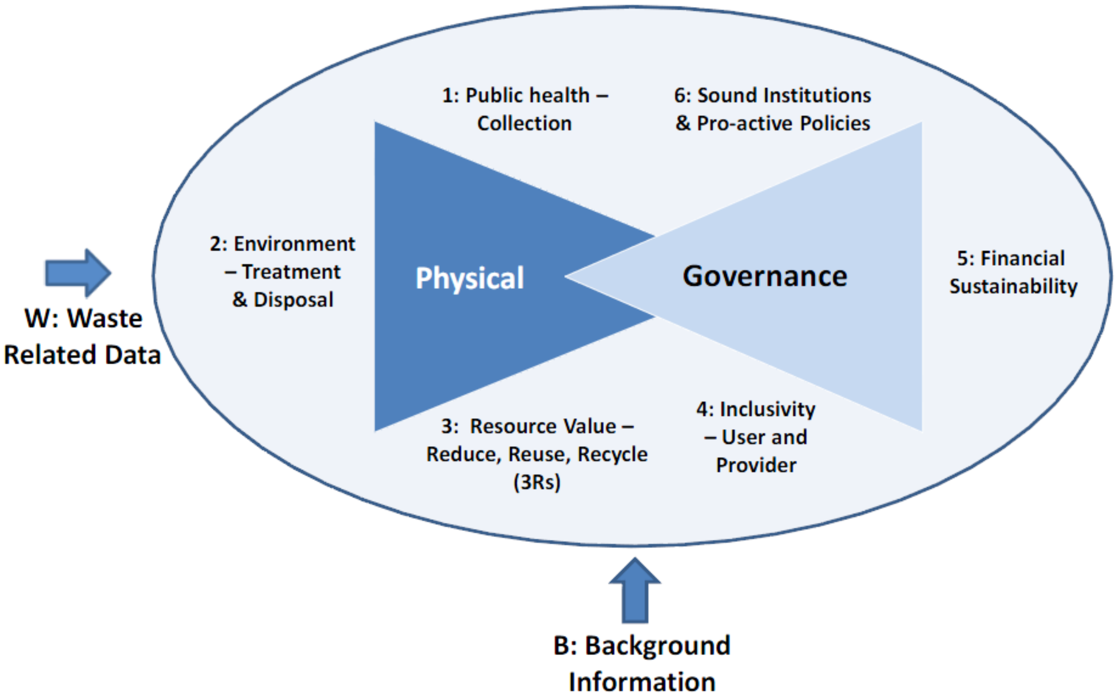

Figure 2-3 Wasteaware ISWM benchmark indicators and its six indicators. Adapted from Wilson et al. (2015)

2-5 Solid Waste Management in Developing Countries

Guerrero et al. (2013) stated that many of the developing countries are generating more MSW than before because of increases in the population, rapid growth of the economy, increased urbanization, and improved living standards. Wilson et al. (2013a) indicated that the MSW generation rate per capita in the developing countries is positively related to the level of income.

The main concern of most of the developing countries regarding the issue of MSWM is waste collection and transport (**Section 2-2-2** and **Section 2-2-3**); many of the authorities in these countries are still not interested in waste recycling or resource recovery (Guerrero et al., 2013). This means that they are trying to hide the problem not to solve it.

It is estimated that 99% of the domestic solid waste generated in the high-income developing countries (GDP = $1600 per capita) in urban places is being collected whereas this percentage is only 45-70% in the lower income countries (Wilson et al., 2013a). Furthermore, this percentage can be lower more in low income countries. For instance, in Nairobi city, in Kenya, (low income), the percentage of collected waste in 1999 varied between 30 - 45% (Henry et al., 2006).

Usually, the waste authorities in developing countries use open dumping to dispose of their MSW, without giving any consideration to the environment (Gardia et al., 2006). Guerrero et al. (2013) stated that this method of waste disposal does not take account of landfill gas, waste leachate collection and treatment, lining (to protect the ground), and infrastructure design. In addition, the locations of these open dumps are chosen to be as far as possible from the city to hide the impact on the surrounding land (Guerrero et al., 2013).

However, recycling is considered one of the best options to treat solid waste in some developing countries. This is usually done through the informal sector. Velis et al. (2012) concluded that 20 – 30% of the waste generated in developing countries is recycled by IRS. One method is for housewives to sort the waste at source and then sell it to third parties (Visvanathan et al., 2006b).

However, the most common method is for waste pickers to sort the mixed waste (from public waste bins, waste transfer stations, and waste dumps and landfills) and collect the recyclable materials (Velis et al., 2012). Many people consider this method of waste sorting and recycling a helpful way of reducing the use of landfills and open dumps and of gaining some profit from the waste, with the profit going to the waste pickers rather than to the waste authority that is paid to manage this waste.

On the other hand, there are many disadvantages to this process, such as health and safety risks to the waste pickers and to the communities (Wilson et al., 2006; Wachukwu et al., 2010). In addition, Velis et al. (2012) reported that there are more problems resulting from the process of IRS, such as crimes, pollution, the lack of tax paid on this activity and the use of children to sort waste.

Overall, the formal recycling sector in developing countries needs to benefit from the experiences of developed countries. Troschinetz and Mihelcic (2009a) summarized the factors affecting recycling in developing countries (based on 23 case studies) as follows:

- authorities' plans for finances and management
- household level of education and income
- the nature and properties of the generated waste
- the method of waste collection and sorting
- the educational advertising campaigns

- recycling facilities and market
- resources and land availability.

Ahmed and Ali (2004) suggested that the cooperation between the authorities and the private sector would be one of the important factors for successful recycling in developing countries while Wilson et al. (2006) stated that implementing a new recycling system would be affected negatively if a newly established formal recycling sector did not consider the existing informal sector so that both sectors can to be integrated in the planning and implementation stages.

2-6 Mega Event Management

At mega events, such as the Olympics, music festivals, and religious gatherings, thousands or even millions of people can gather in a specific place just for several days. Sometimes, as usually happens at mega events, they sleep at the event site in tents. A mega-event is defined as a sporting or cultural event that has a large global audience and media coverage (Roche, 2002).

Many organizations, such as the United Nation Environment Programme (UNEP), make a huge effort to make these events 'green' by reducing the environmental impact. UNEP defines 'green events' as those that do not have a negative impact on the ecosystems or the environment (UNEP, 2007). In addition, the International Organization for Standardization (ISO) developed a standard for sustainable event management, namely, ISO 20121 (ISO, 2012). This standard requires the event organizers to consider social and environmental issues in order for the event to be classed as green (ibid). Thus, it is very important to increase event managers' level of environmental care. Event organizers should also consider and utilize the experiences of other event managers to achieve sustainability, with consideration being given to environmental rules and regulations; all of this should occur in the planning phase of the event (Ponsford, 2011).

Andersson and Lundberg (2013) reported that the main concerns in the tourism events (such as music festivals) are the social impacts as well as economic impacts while the environmental impacts are given the last priority. In addition, Collins et al. (2009) found that the environmental impacts of a huge event (such as a mega sport event) have long-term effects. For instance, although the Olympics are probably the most widely known examples of attempts to reduce the environmental impacts (for example, by using green building techniques and recommending the use of public transport), the overall impact assessment is difficult to quantify, especially the long-term impacts (Collins et al., 2009).

2-6-1 Solid Waste Management at Mega Events

Big events generate huge quantities of waste because the people involved in the events need at least to eat and drink. Many event managers try hard to control waste generation, as the cost of waste collection and disposal is very high (Cierjacks et al., 2012). It is very important (from the environmental perspective) for these quantities of waste to be managed properly by aiming for sustainability via resource recovery and the production of zero waste. Zero waste means that there is no waste sent to the landfill but rather waste is managed through the 3Rs (**Section 2-2-5**) (Jones, 2010). The first time this concept was applied completely to the Olympics was in the London Olympics 2012 (as part of the green Olympics). The plan was to recycle (or compost) and reuse 70% of the domestic solid waste generated during the London Olympics and Paralympics 2012 and incinerate the rest with energy recovery (Sullivan, 2012). Since 1994, any city that has wanted to host the Olympics has been required to have a comprehensive environmental programme (Karamichas, 2013). Furthermore, in terms of sustainable event management in the Olympics, Sydney Olympics is considered as the reference template for the concept of green sustainable Olympics (Cox, 2012).

The planning of a green event needs to consider many issues, especially the issue of managing waste. Solid waste production at events depends on three main factors: tourists' density, tourists' behaviour, and the location characteristics (Cierjacks et al., 2012). Thus, Williams et al. (2006) summarized the main factors that must be taken into account to plan successful waste management as follows:

- event type and background
- identification of waste: type, generators, location of production and infrastructure
- waste management educational campaigning
- recycling possibility
- how waste will be handled and managed during the event.

This plan should be done and tested before the event. Usually, this plan is made and performed under the supervision of international environmental organizations, such as United Nations Environment Programme (UNEP). For instance, in 2005, UNEP started to help the Beijing Olympic Committee of the Olympic Games (BOCOG) execute its environmental plans and projects as required and as an important aspect of the preparation for the Games (UNEP, 2007). One of the most important elements was SWM and how the BOCOG should apply the 3Rs to avoid any negative environmental impact of the solid waste and to achieve the goal of a green Olympics (ibid).

2-6-2 Apply the 3Rs at Mega Events

The 3Rs (**Section 2-2-5**) cannot be performed in isolation; instead, the whole SWM system should be planned and designed based on them. In addition, there should be such a system to serve the whole community first, and then this system can be used during any event in the same community. For instance, BOCOG designed and implemented a system for the public before the event, and then they designed a specific dedicated system for the event.

Solid waste management at Beijing Olympics 2008

BOCOG was responsible for SWM during the event and aimed to reach the goal of 100% sorted waste and 50% recycled waste (UNEP, 2007). In order to achieve this, Beijing established a recycling system for the public throughout the entire city to make them sort their waste, at source, into three groups, that is, recyclable materials, compostable materials, and the rest of the waste, with a target of 50% sorted and 30% recycled (UNEP, 2009).

Moreover, to increase the awareness of the importance of waste sorting at source, the government distributed 300,000 printed brochures, 100,000 posters and 1 million of a variety of publicity materials (UNEP, 2007). In addition, the number of waste treatment plants was increased from 17 (2003) to 32 in 2008 (UNEP, 2009). As a result, 3 million people in that city were committed to sorting their waste at their houses, and many farmers started to use on-site composting facilities to treat their own organic waste and to produce compost.

After that, the waste plan was tested in 2006, during the 11th World Softball Championships at which 88.6% of the total waste (48,734 kg) was recycled and the rest safely treated and disposed of (UNEP, 2007).

Solid waste management at festivals

Another good example of green events is music festivals. Usually, bottles, cans, and cups constitute a big portion of the solid waste generated during these events. Therefore, successful waste management during the festival requires organizers (for example) to control the sale of drinks such as beer, water, and soft drinks. Cierjacks et al. (2012) suggested that the behaviour of the festival's visitors can be changed by setting up a good system of waste reuse and reduction.

One of the most successful methods, which is followed in the UK, is to take deposits on these items; the deposit is refundable if the buyer returns the cup or the bottle to be reused or recycled (Jones, 2010). There are many examples of how these strategies have been successful; at the Rothbury Festival, 70% of generated waste was recycled, 23% was composted, 6% disposed of in the landfill, and the remaining 1% given as donations to charity (ibid). At this event, people were required to pay a deposit when they bought anything inside the festival venue; for instance, they paid GBP 0.1 extra for each bottle or cup (ibid). Another way to control the waste at these events is to educate people by means of brochures and posters, encouraging them to reuse their cups and bottles if so designed.

However, many researchers have argued that this method can control the waste disposal but not the waste generation. Thus, a better method was introduced in 2002, which was the usage of reusable dishware (Tchobanoglous et al., 2006). This method decreased the total weight of waste generated in the Whole Earth Festival at the University of California by 27% and reduced its volume by 62%; in addition, the waste generation rate per visitor dropped from 0.22 to 0.19 $kg.p^{-1}.d^{-1}$ (ibid).

CHAPTER 3

AIM AND OBJECTIVES

3-1 Knowledge Gap

Based on the background presented in **Chapter 1** about SWM in Mina during the Hajj and according to the literature review in **Chapter 2** about SWM in developing countries and in mega events, it was necessary to assess SWM in Mina during the Hajj as there is no prior research on this topic. ISWM is an important and widely used tool for such an assessment. In particular, the work of Wilson et al. (2015) in taking and developing the conceptual Wasteaware model shown in **Figure 2.3** as a benchmarking tool provides a structured approach to assessing the status and sustainability of a city's waste management system.

As the Hajj at Mina is both a mega event and has the effect of creating a temporary city, the Wasteaware ISWM benchmark indicators could be used to benchmark the SWM system in Mina. Although it is recognised that the nature and scale of the problems and solutions for a mega event as opposed to an established city would differ, the aim in adopting this tool was to ensure this study is comprehensive and to help to identify the key issues to be addressed from a waste and resource management perspective.

In addition, as noted in **Chapter 2**, many environmental organisations require event organisers to consider the 3Rs as the main option to handle waste thus reducing the organisers' need for waste disposal in landfill. Barber et al. (2014) reported that although there is very limited research on the environmental development of festivals and events, there are no studies on the visitors' intentions and behaviours toward SWM and waste recycling during these events.

However, in Mina during the Hajj, recycling has not yet been considered as an option for waste management. Thus, the original contribution to the knowledge presented in this research was to investigate the pilgrims' recycling intention and compare and contrast it with their behaviour, which was derived from implementing a waste recycling scheme during this event through an exemplar project (**Chapter 6**). To address this, a background about the present SWM in Mina was established as well as feedback from camp managers and from pilgrims (**Chapter 5**). Based on all of this, novel insights can be gained for the design of a future full-scale recycling system during the Hajj and other similar events.

3-2 Aim and Objectives

The overall aim of this research is to study and assess the current SWM in Mina during the Hajj, identify the main challenges, with a view to investigating the possibility of introducing recycling scheme through an exemplar project. To meet this aim, this research focused on the following objectives (**Figure 3-1**):

OBJ1- **To establish a background about SWM in Mina and assess it based on the researcher's observations, collected data, and interviews with official from the Mina authorities.** These included identifying sources of waste in Mina and how such sources are managed, estimating the quantity of waste in Mina's streets, and categorizing the waste composition in the Mina camps. All of these elements, in addition to all collected data from Mina authorities combined with the on-site observation, was used to assess SWM in Mina by using the ISWM framework (Wasteaware ISWM benchmark indicators). Then, based on this framework result, the needed improvement for the system is suggested.

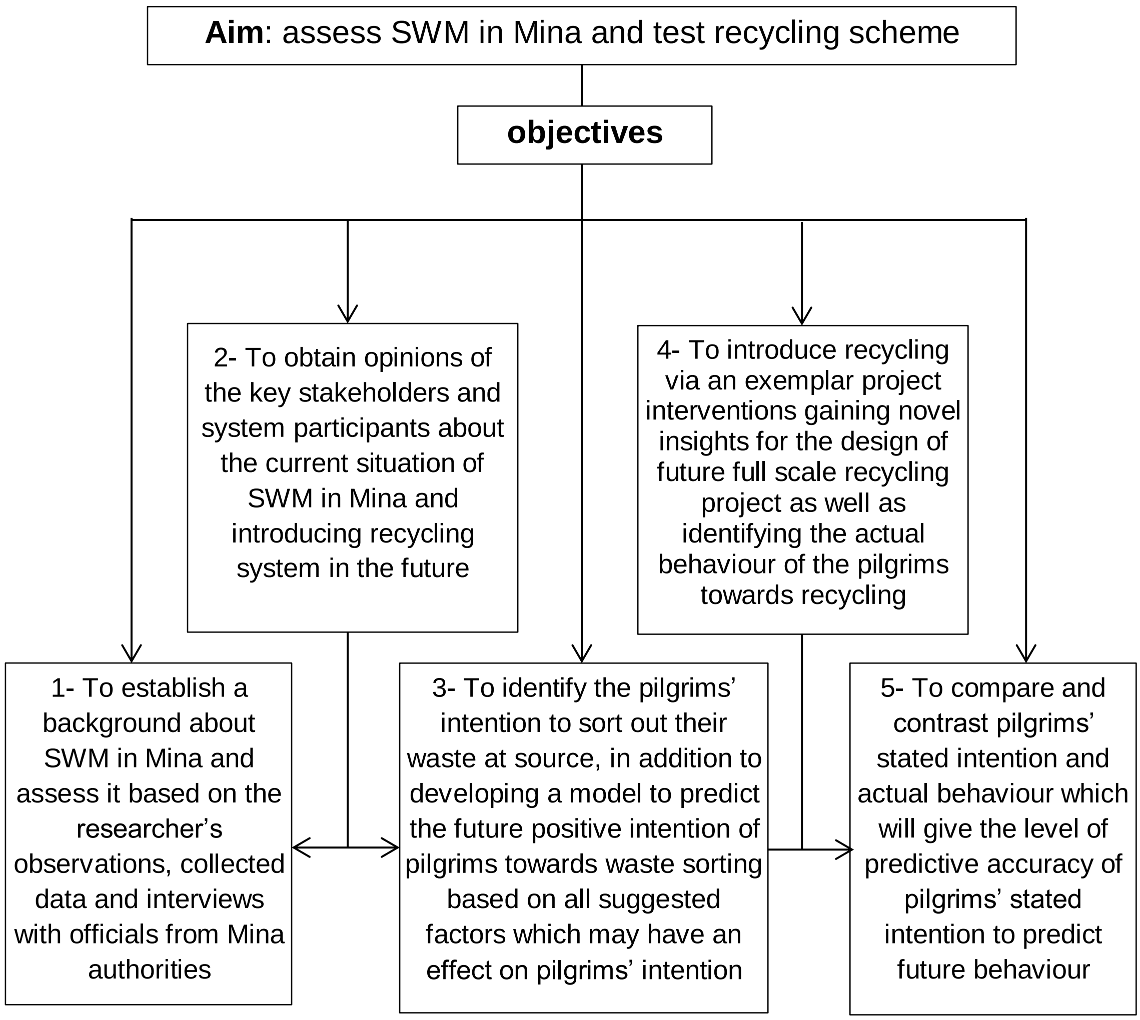

Figure 3-1 The overall aim of this research combined with the objectives

OBJ2- **To obtain the opinions of the key stakeholders (camp managers) and system participants (pilgrims) towards the current situation of SWM in Mina and introducing recycling system in the future.**

OBJ3- **To identify the intentions of the pilgrims to sort out their waste at source, in addition to developing a model to predict the future positive intentions of the pilgrims towards waste sorting based on all suggested factors that may have an effect on the pilgrims' intentions.**

OBJ4- **To introduce recycling via an exemplar project, thus providing novel insights for the design of a future full-scale recycling project as well as identifying the actual behaviour of the pilgrims towards recycling.** This can test if the potential solutions can be transferred to a practical project during mega events such as the Hajj.

OBJ5- **To compare and contrast the pilgrims' stated intention (OBJ3) and actual behaviour (OBJ4), which will give the level of predictive accuracy of the pilgrims' stated intention for predicting future behaviour.** Then, the aim was to identify the factors that may affect the pilgrims' recycling intention and behaviour.

3-3 Thesis Structure

This thesis is consists of eight chapters, which are presented as follows:

Chapter 1 introduces a general background about Saudi Arabia, Makkah city and the Hajj as well as information about the SWM in each one.

Chapter 2 provides a literature review of studies about SWM, concentrating on resource recovery ae well as recycling system design and the factors affecting waste sorting intention and behaviour. Also, SWM in developing countries is highlighted. However, the main focus of this chapter is to present examples of SWM during mega events, which have considered recycling as the main method for waste disposal. In addition, the use of the ISWM framework as a tool to assess SWM is presented.

Chapter 3 presents the aim and objectives of this research, which were derived from the knowledge gap based on the previous chapters.

Chapter 4 focuses on how the research design and methodology were used to achieve the aim and objectives of this thesis. Also, the procedures and the reasons behind applying these methods are presented.

Chapter 5 contains the results on the current situation of SWM in Mina, which explain the current situation of SWM in Mina during the Hajj based on the methodology presented in **Chapter 4**. These results are used to build the Wasteaware ISWM benchmark indicators framework for the SWM system in Mina. In addition, based on the methodology, the opinions of the camp managers about the current SWM in Mina and the alternative recycling system are investigated. Moreover, the pilgrims' intention to sort their waste at their camps are examined in addition to the factors that affect such intention, especially the pilgrims' recycling background and habit as well as their assessment of SWM in Mina.

Chapter 6 includes all the results derived from implementing the exemplar project (waste sorting project) in three camps according to the methodology (**Chapter 4**).

Chapter 7 discusses all the results presented in **Chapters 5** and **6** along with the background and literature review in **Chapters 1** and **2** to achieve the aim and objectives of this research.

<u>Chapter 8</u> presents the summary of findings on each of the objectives of this research (**Chapter 7**) and offers suitable recommendations to enhance and improve SWM in Mina during the Hajj, which is the aim of this thesis.

CHAPTER 4

METHODOLOGY

4-1 Introduction

The aim of this research is to assess the present solid waste activities in Mina during the Hajj and to test a proper alternative to enhance the management of solid waste in Mina. To achieve the overall aim and objectives, several research methods were used taking into account the limited time available to conduct the fieldwork especially in such a small, crowded area (**Figure 4-1)**.

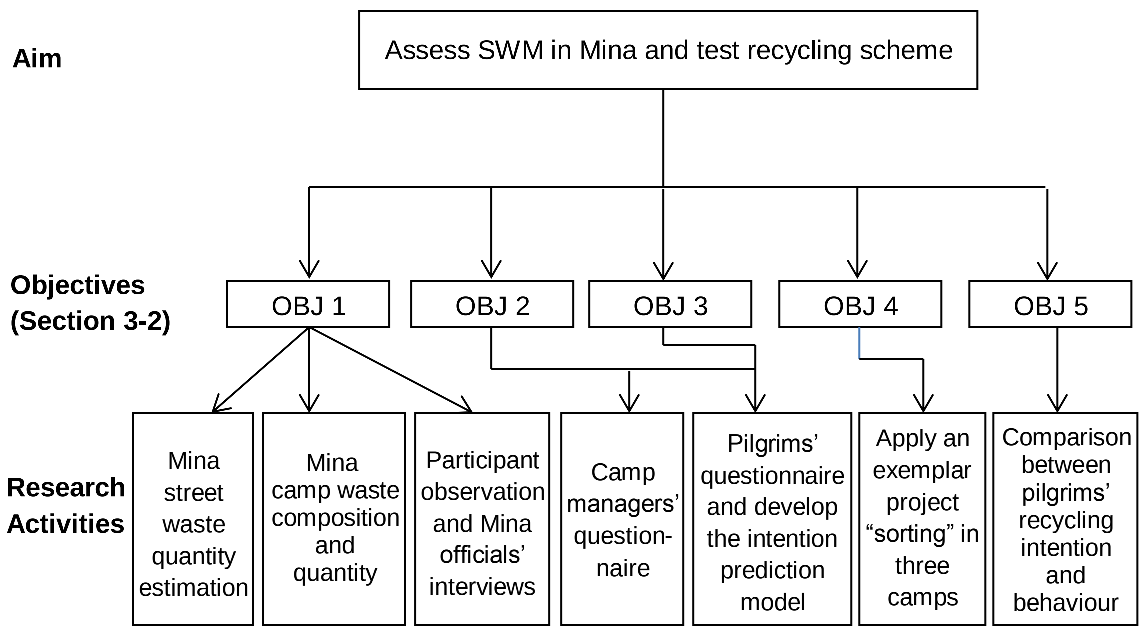

Figure 4-1 The research methodology and its relation with the research aim and objectives

4-2 Research Design

The methodology is based on insights pertaining to SWM in developing countries, Saudi Arabia, Makkah city, and Mina; event management; and the design of waste recycling systems (**Chapter 1** and **Chapter 2**). The following research methods were used (**Figure 4-1**):

- participant observation (interviews with officials from the Mina authorities, on-site observation, and interviews with the managers of the three camp where the exemplar project took place)
- identification of waste composition for the Mina camps
- estimation of quantity of solid waste in Mina's streets
- assessment of SWM in Mina by applying Wasteaware ISWM benchmark indicators
- multiple-choice questionnaires (for camp managers and pilgrims)
- development of a recycling intention prediction model
- application of exemplar project (waste sorting project)
- comparison between pilgrims' recycling stated intention and actual behaviour

More details about the relationship between the research objectives and the research methods as well as the supportive references for the chosen research methods are given when each research method is described in detail. The implementation of the research methods was divided into two Hajj years (**Figure 4-1**). In the first year, the conducted fieldwork aimed to formulate a general background about the current situation of SWM in Mina, whereas the second one concentrated on applying alternatives through performing the exemplar project (waste source separation) and using the pilgrims' questionnaire to evaluate the pilgrims' intention to sort their waste.

4-3 Participant Observation

Participant observation (a technique of learning a routine for a group of people in an activity, ritual, or event) includes interviews (formal and informal) and observations (considered as the starting point of the research fieldwork to study a cultural (ethnographic) phenomenon for a group of people) (O'Leary, 2004; DeWalt and DeWalt, 2011).

The observation technique was used in the two periods of fieldwork. The first one included the on-site observation (**Section 4-3-1**) and interviews with officials from the Mina authorities (**Section 4-3-2**) while in the second period, it was used in observing the sorting behaviour and interviewing the three camp managers (**Section 4-9-5**).

Mackellar (2013) stated that that the participant observation method can reveal a new view of people's behaviour and anticipation that allows the researcher to study the event in great depth. In addition, to ascertain that the researcher's opinion does not affect participant observation, DeWalt and DeWalt (2011) suggested that the researcher should be open-minded and honest in his/her questions and observations. Thus, photographs were taken along with the observations so that comments made at the time could be checked against the photographic evidence later on. These photographs were taken after permission from Mina authorities had been granted and the all of the fieldwork had been given ethical approval by the University of Leeds with Ethics Reference: MEEC 12-008.

4-3-1 On-site Observation

The aim of using this method of research was to obtain a comprehensive background to the present situation of SWM in Mina (part of **OBJ1**, **Section 3-2**). Through this observation, the researcher was able to discern some of the SWM challenges in Mina. In addition, the pilgrims' behaviour in solid waste generation and how they dealt with their waste was observed; the areas of waste generation were recorded along with their sources.

The on-site observation took place in streets, camps, service facilities, and shops to record how waste was disposed of and whether there were any infringements. At the same time, the cleaning workers' behaviour and working habits were observed and recorded.

4-3-2 Interviews with Officials from Mina Authorities

The main aim of these interviews was to obtain undocumented data and information about the problems (as much as possible) of SWM especially and the Hajj generally (part of **OBJ1**, **Section 3-2**). The interviews were conducted with many people who were considered as part of Mina authorities, for instance, the manager of the Mina area in the Makkah Municipality (Alsebaei, 2010), the assistant deputy minister for Transport, Projects, and Sacred Sites Affairs; and the head of the Cleaning Department in Makkah Municipality. The last two interviewees preferred to provide the researcher with unpublished reports about the Hajj instead of having a conversation about the situation (Cleaning Department, 2010; Ministry of Hajj, 2010). These two reports included the following information (**Chapter 1**):

- general information about Tawafa companies
- number of pilgrims from each country
- the number of pilgrims in some of the Mina camps (when available)
- map showing Mina and how the camps are distributed

- the total weight of each compactor box but without the information about which camp or street it served
- the total quantity of solid waste generated in Mina during the Hajj and disposed of in the landfill over six years
- the total quantity of solid waste generated in Makkah city and disposed of in the landfill during the whole year
- some other information mentioned in the background from these two sources.

4-4 Solid Waste Quantity Estimation for Mina's Streets

The amount of waste generated in Mina's streets (litter) is unknown and, as mentioned in **Section 1-7-1,** waste is produced from many sources. Although there are between 3000 and 5000 cleaning workers during the event to clean Mina's streets (**Section 1-7**), waste still accumulates (as could be observed). Therefore, the estimation of the quantity of this litter is necessary in order to plan a method for its management.

This research focused on two main streets in Mina, namely, Alkaif Street (maximum crowds, pilgrims' camps, toilets, mosque, and food shops), and Souq Alarab (maximum crowds, pilgrims' camps, toilets, as well as service streets, that is, small streets where pilgrims can find food shops, pharmacies and restaurants). Both of the main streets lead to Aljmarat Bridge, to which all pilgrims should go once a day (**Figure 4-2)**.

Not all the pilgrims spend five days in Mina, but the second, third and fourth Mina days are the most crowded, as the pilgrims have to stay in Mina. Because of this, the street waste samples were collected during these days: 16, 17, and 18 November 2010. There were fixed places identified before the beginning of the event on each street from which samples were collected; at each place, the sample was collected from the left edge, the centre, and the right edge of the street, from an area of 1 m^2 (L=1 m × W=1 m). These places were chosen based on the existence of possible sources of littering. These chosen spots were at the camp entrances, the mosque, toilets, shops, restaurants, and shaded places (**Figure 4-3** and **Figure 4-4**). **Tables 4-1** and **4-2** explain the areas adjacent to the selected points in both streets where the direction was set up according to the pilgrims' movement when heading to the Aljmarat Bridge.

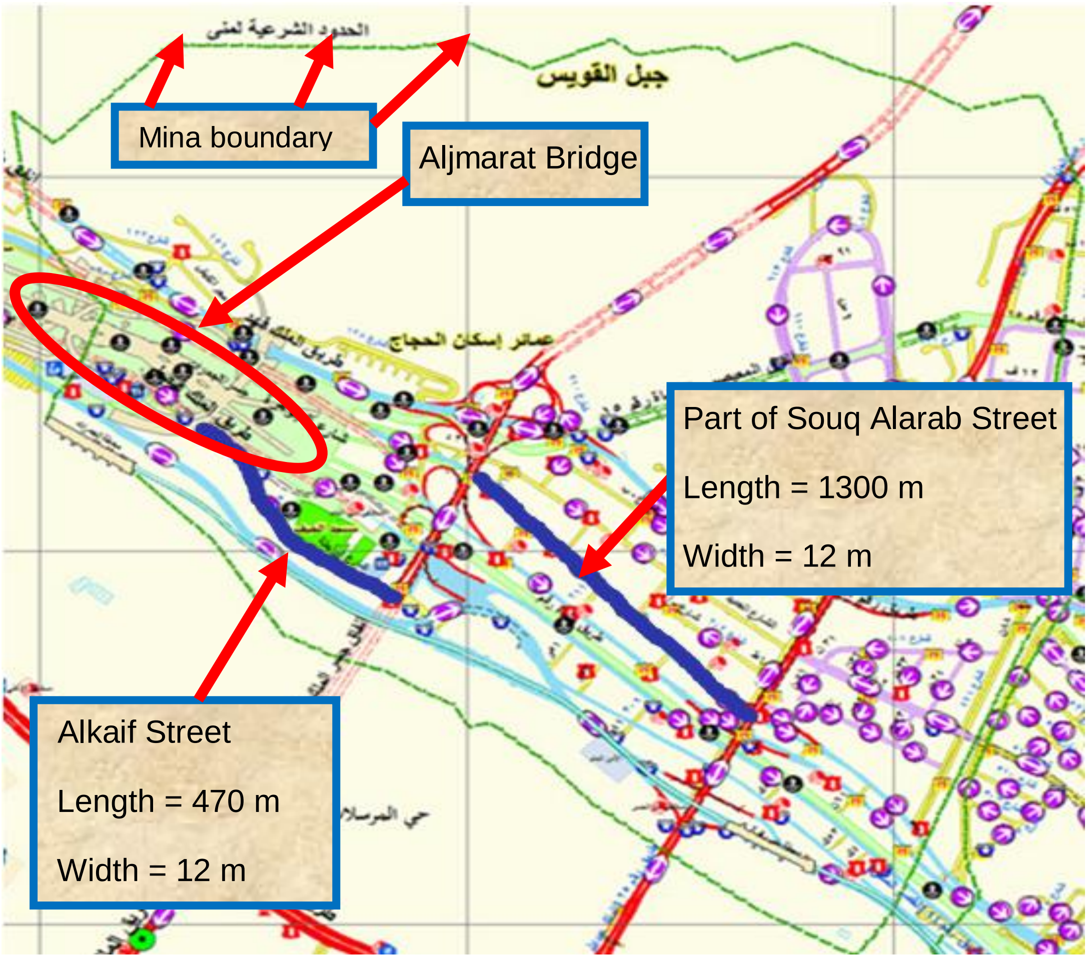

Figure 4-2 The two chosen streets in Mina where waste quantity was estimated

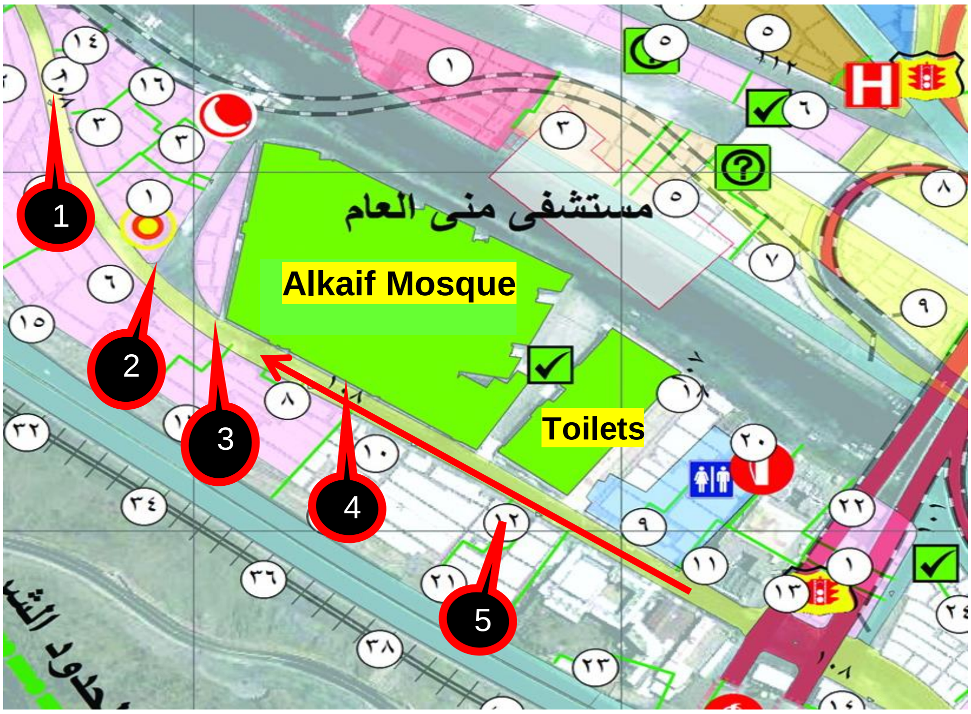

Figure 4-3 The selected points in Alkaif Street

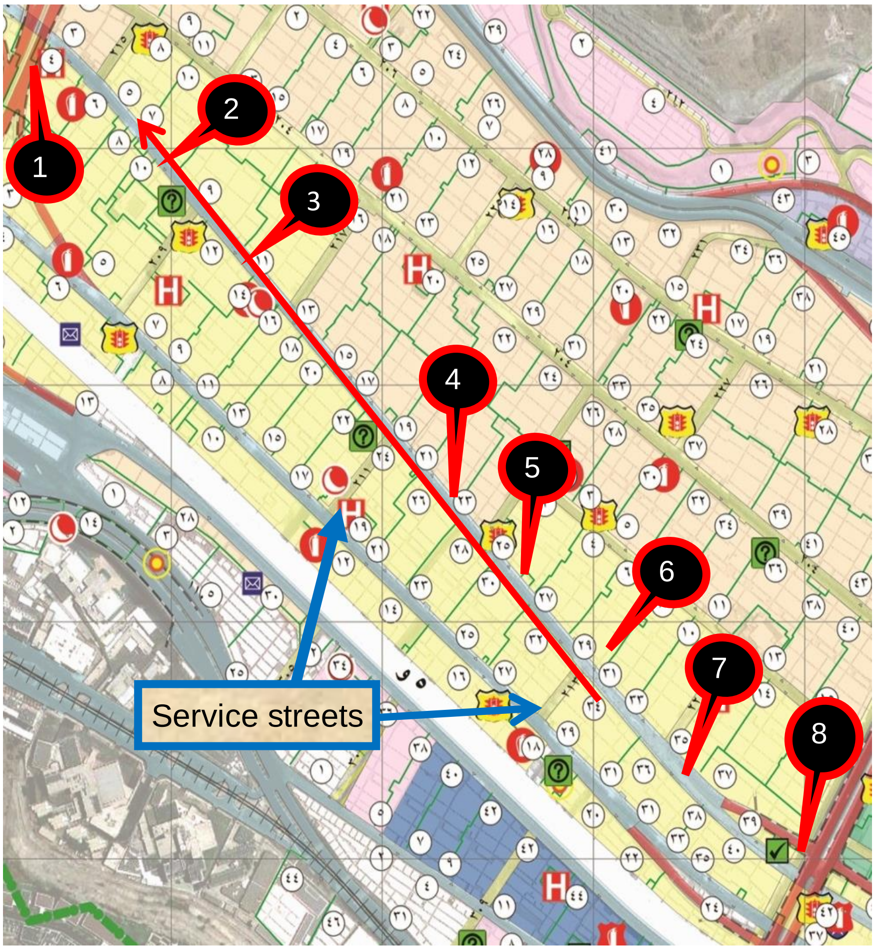

Figure 4-4 The selected points in Souq Alarab Street

Table 4-1 The possible source of littering in the selected spots of waste sampling in Alkaif Street

Point No.	What is on the left of the street	What is on the right of the street
1	VIP Saudi pilgrims' camp entrance	VIP Saudi pilgrims' camp entrance
2	VIP Saudi pilgrims' camp	Street intersection
3	VIP Saudi pilgrims' camp	Street intersection
4	Pharmacy	Alkaif Mosque
5	Food shop	Alkaif Mosque toilets

Table 4-2 The possible source of littering in the selected spots of waste sampling in Souq Alarab Street

Point No.	What is on the left of the street	What is on the right of the street
1	Shaded area under King Khalid Bridge	
2	Pilgrims' camp	Indian pilgrims' camp entrance
3	Street toilets	Street toilets
4	Service street	Pilgrims' camp
5	Pilgrims' camp	VIP Pakistani pilgrims' camp entrance
6	Pilgrims' camp	Service street
7	Indian pilgrims' camp	Qatari pilgrims' camp entrance
8	Shaded area under King Abdullah Bridge	

The samples were collected consecutively starting from the first point and going through to the last one in the street (**Figure 4-3** and **Figure 4-4**). After the sample collector had finished the last place in the street, he would start again from the first place until the end of his time interval (about 8 hours). The time interval was established based on the starting point (not the ending), which means the collector may have started his shift on time but may have finished the last place after his shift had finished. As a result, sometimes the next samples collector might have started from the beginning while the previous one had still not finished his lap.

The researcher noticed that the area affected by waste accumulation at the edges of the streets was between 1 - 2 m in width. Therefore, to estimate the total quantity of the solid waste at the street edges, two assumptions were made; the first one was assume that the width of the area covered by waste at the edges equals 1 m, and the second assumption, 2 m. Moreover, the average of all waste samples which were taken from the left, centre and right edge of each street was calculated in order to estimate the total quantities of solid waste on the street at any given time.

4-5 Waste Composition for the Mina Camps

This method of research was designed with the purpose of identifying the material composition of the solid waste generated within the pilgrims' camps in Mina (part of the **OBJ1**, **Section 3-2**). It was done based on international standards (USEPA, 2002a; ASTM, 2010) and adjusted to the local conditions. The methodology includes sampling, sorting, and statistical analysis.

4-5-1 Sampling Plan

The goal of the sampling plan was to estimate the size of a representative sample according to the international standards (USEPA, 2002a; ASTM, 2010) as well as the basic statistics. To obtain representative samples, the population was identified as well as the waste major components.

The sampling population

The sampling population in this project was divided into two parts: i) the compactor boxes in the Mina camps, and ii) the waste bags inside the compactor box. Thus, the sampling plan consisted of the following steps:

1- Choose number of the Mina camps and mark its compactor boxes to track them to the landfill (the first population).
2- Obtain a representative sample from each compactor box according to the sampling plan (the second population).
3- Sort the sample to identify the waste composition.

1- <u>First sampling population: compactor boxes</u>

There were 723 camps in Mina (**section 1-2**), which served pilgrims from 181 countries (Ministry of Hajj, 2010). These camps were not evenly divided between those countries, because the number of pilgrims was not the same for each country (based on the ratio of 1000 pilgrims for each million Muslims for each country (Ministry of Hajj, 2010)).

The total sampling population in this case was 723 compactor boxes (as each camp should have a compactor box). To select a representative sample from those boxes there were criteria for the selection that considered the variety in the camps' characteristics and properties as well as the similarities between them. The sampling selection criteria of the Mina camps were the following:

1. Include camps from the countries with the highest number of pilgrims.
2. Include all Tawafa companies (**Section 1-2**).
3. Do not choose two camps from the same country (to include more countries).
4. Exclude pilgrims from Saudi Arabia from the third criterion because there were about one million pilgrims or more, which represented 30% to 40% of the pilgrims in Mina (CDSI, 2011). In Hajj 2010, there were 263 camps for legal pilgrims from Saudi Arabia in Mina, which represented 36.4% of all the Mina camps (Ministry of Hajj, 2010). Those camps were divided into five different grades according to their

location and cost. Grade A camps were the most expensive with VIP services and the best location, whereas grade E camps were the most affordable, but were at the worst locations.

The representative sample was estimated according to a *stratified random sample* method. In this method, the population is divided into groups (in this case they were the Tawafa companies), and then the samples were collected from each group using the simple random sampling method (where each camp had the same probability of being chosen randomly) (Millard et al., 2001). Thus, each country's camps had the probability of being chosen one time, but once a camp from a certain country had been selected, the remaining camps from the same country were excluded (according to the previous criteria).

<u>The size of the representative sample from the first population (Mina camps)</u>

The sample size was estimated based on **Equation 4-1** (Cochran, 1977), which is the simplest and most common equation used to estimate sample size.

$$n = \frac{np}{1 + \frac{np - 1}{tp}}$$ **Equation 4-1**

Where: n = the final sample size

np = primary sample size, **Equation 4-2**

$$np = \frac{Z^2 \times SD\,(1 - SD)}{C^2}$$ **Equation 4-2**

Where: Z =1.96 at level of confidence = 95%

Confidence interval (C) = 15%

Total population (tp) = 723 camps

Standard deviation (SD) = 0.5

Therefore: np = 42.7, and n = 40.

The estimated representative sample size in this case was 40 camps (5.5%) of the Mina camps.

Where to collect samples from

According to the Ministry of Hajj (2010), with the exception of Saudi Arabia, there were 17 countries with the highest number of pilgrims (**Table 4-3**) which were distributed between all Tawafa companies. Thus, 17 camps from those 17 countries were chosen (according to the first and second criteria) as well as five Saudi pilgrims' camps from the five grades (the fourth criteria). The rest of the sample (19 camps) was randomly chosen from the Mina camps based on the third criterion.

Makkah Municipality numbers each compactor box. After the end of the Hajj, Makkah Municipality immediately transports all the compactor boxes to the landfill to be emptied (**Figure 1-15**). Thus, after the camps had been chosen, the number on each compactor box was recorded. This facilitated identification of the boxes at the landfill to obtain the samples.

Table 4-3 Countries with the highest number of pilgrims in Hajj 2010 in order. Adapted from Ministry of Hajj (2010)

No.	**Country**	**Number of Pilgrims**
1	Indonesia	221,000
2	India	170,491
3	Pakistan	159,647
4	Iran	106,500
5	Bangladesh	100,000
6	Turkey	100,000
7	Western Europe	95,407
8	Nigeria	95,000
9	Egypt	78,138
10	Algeria	36,000
11	Malaysia	36,000
12	Afghanistan	35,000
13	Sudan	34,110
14	Morocco	32,000
15	Iraq	30,500
16	Eastern Europe	25,500
17	Syria	25,000

2- Second population: waste bags

After the number of the representative sample had been estimated from the compactor boxes, the sample size from each box (waste bags) was obtained. Usually camp waste is collected in big black garbage bags and disposed of in this form (**Figure 1-15, Figure 4-5**). Thus, the number of waste bags needed in each sample was calculated.

To determine the number of bags in each sample, the total number of bags in the compactor box was estimated based on the following assumption: all waste bags were 90% full of a homogenous mix of household waste whereas the remaining 10% of the volume was assumed to be unused (necessary space for the bag to be fastened). Cleaning Department (2010) stated that the estimated volume of the black waste bags used in the Hajj is equivalent to 50 gallons (0.227 m^3). The volume of 90% of the waste bags is 0.2043 m^3.

The number of bags in the compactor box (NB) was estimated based on the total capacity of the boxes (**Equation 4-3**). Cleaning Department (2010) reported that the estimated capacity of the compactor boxes used in Mina is 8000 kg, where the total volume is equivalent to 20 m^3 with an estimated waste density of 400 $kg.m^{-3}$. In addition, Diaz et al. (2005) estimated the bulk density of loose waste to be between 90 and 178 $kg.m^{-3}$, with an average of 134 $kg.m^{-3}$. Therefore, the expected weight of each waste bag in the Hajj (at a density of 134 $kg.m^{-3}$) is 27.4 kg (134*0.203).

$$\mathrm{NB} = \frac{\text{The capacity of the compactor box (kg)}}{\text{The expected weight of each waste bag (kg)}} \qquad \textbf{Equation 4-3}$$

Based on **Equation 4-3, t**he number of bags that fit into the compactor box (NB) is about 292 bags.

Figure 4-5 The method of collecting waste in the compactor box, where waste is collected in waste bags and disposed of in the compactor box

The size of the sample from the population part one (Mina camps)

Since the waste in the compactor boxes is placed in bags that all have the same volume, according to EPA (2002a), the sampling method used in this situation can be simple random sampling. In this method of sampling, which was adopted in this research, the number of samples (n) should be randomly collected from the compactor box, but each bag should have an equal chance of being chosen in the selected sample.

To estimate the size of the sample from each compactor box, the international standard of obtaining waste composition, namely, ASTM D5231-92, was used (ASTM, 2010). This method of sampling suggests that the representative sample, which can characterize the waste composition, can be in the range of 91 to 136 kg from each waste vehicle load of unprocessed waste (ASTM, 2010), which is equivalent to the compactor box load. This means that the sample can be between 3.3 to 5 bags if all bags are 90% full with a homogenous mix of household waste.

It is to be expected that the type of waste inside each bag in the Mina camps depends on each bag's location and the kind of waste generated in that area. For instance, a waste bin in the kitchen may have a different kind of waste from that of a bin beside the tea and coffee tables. Subsequently, it is expected that some waste bags will be heavier than others because of the density of the waste inside the bags; for instance, a bag can weigh 1 kg if it is filled with just plastic film whereas this figure will be much greater if the bag is filled with food residuals.

Thus, as a safety factor, the number of bags should be doubled or tripled to obtain an adequate sample from each compactor box. Therefore, this research assumed that the sample size should be within the range of 5 to 15 waste bags from each compactor box, which should be collected from different areas of the box as recommended in the methodology of the simple random sampling method (USEPA, 2002a).

4-5-2 Sorting

The sorting was devised to make possible the identification of major waste components that it was anticipated would be found in waste from the Mina camps.

<u>*Waste components to sample for*</u>

According to the limited information available in the pilot study by Aziz (2007), the main components of waste in Mina (more than 5%) were identified as shown in **Table 4-4**. Although anecdotal evidence (from officials) suggests that items such as glass are prohibited in Mina, it appeared in Aziz's (2007) waste composition in significant quantities (about 3%). There were also 16.6% of unidentified waste components in that pilot study. Thus, in this research, the number of waste categories was expanded to seven to cover, as much as possible, the main waste categories in the Mina camps (**Table 4-5**).

Table 4-4 Major waste components in Mina in 2007. Adapted from Aziz et al. (2007)

Waste component	Organic	Plastic	Paper and cardboard	Metals and aluminium	Others
Percentage %	39.4	11.8	19.4	5	16.6

Table 4-5 Waste categories covered in this research

Waste category	It contains
Organic waste	Food residuals and other organic
All plastic	Plastic bottles, plates, spoons, other hard plastic and plastic films (packaging nylon, disposable plastic table sheets and plastic bags)
Paper and cardboard	Paper juice bottles, cardboard and other kind of paper
All metals	Aluminium cans contain carbonated beverages, aluminium foil, food tin and other ferrous metal.
Glass	Any kind of glass
Cork	Any kind of cork
Textile	Textile, leather, mats and clothes

Sorting plan

The followed sorting plan was based on the ASTM standard (2010), which required each sample to be sorted manually, as it was received, with one pile for each of the main waste categories mentioned in **Table 4-5**. To obtain a clearer understanding about the main waste components in the Mina camps, the seven waste categories were divided into ten groups of waste. The 'all plastic' category was further spilt into 'plastic films' and 'other plastic' while the 'all metals' category was split into three groups ('aluminium cans', 'aluminium foil' and 'other metals'). This was done according to the sorting form in **Table A1** in **Appendix A**.

4-5-3 Statistical Analysis

After the data had been gathered from the sorting of samples, basic descriptive statistics were performed to find the average of each component and the lower and upper level of confidence intervals at a 95% level of confidence. The level of confidence is defined as the calculated boundaries where it is believed the actual mean falls (Field, 2009). Based on this, for each waste component, the average was estimated and the boundaries in which it is believed the actual mean would fall were calculated at a 95% level of confidence.

Then, the results of each waste component were divided into six groups based on the Tawafa companies. This grouping method facilitated the comparison between different countries (as similar countries are grouped together in one Tawafa company by the Mina authorities). The comparisons were done by using the T-test for independent samples by group at a 95% level of confidence. STATISTICA (2011) was used to perform the T-test. The results of the T-test included a p-value, such that if it was less than 0.05 (at a 95% level of confidence), the difference between the two compared groups was considered statistically significant.

4-6 Assessment of Mina's SWM System by Wasteaware ISWM Benchmark Indicators

The initial steps in using the Wasteaware benchmarking tool involve defining / determining key characteristics of the city, its population, and its municipal waste generation. For established communities, this would be a relatively simple task, but in the case of the Hajj in Mina, it was not. Firstly, decisions had to be taken regarding whether to include Makkah city given its close location (**Figure 1.1**) and that the waste is disposed of by this municipal authority, what waste flows to use, and how to characterise the "inhabitants", i.e., pilgrims, in terms of income and other socio-economic factors.

Although any solutions will undoubtedly need to interact with the waste management system for Makkah, the waste generated, albeit very significant over the short term, has a relatively small impact on the main disposal facility (Makkah landfill) over a full year. Perhaps of more importance are the numbers of people involved. Makkah city has a population of around 1.68 million (**Section 1-4**) compared to the temporary population of around 3.69 million pilgrims in Mina (legal + illegal pilgrims) (**Section 1-2**). The Mina pilgrims (from 181 different countries) are highly diverse in terms of background education, ethnicity, culture, and economic standing compared to the population of Makkah City or Saudi Arabia as a whole.

Thus, to assess SWM in Mina by using the ISWM benchmark indicators (part of **OBJ1**, **Section 3-2**), it was decided that Mina would be considered in isolation as a small city with a population of 3.69 million capita, but inhabited for only five days a year. As the Mina community consists of pilgrims from 181 countries, some of the demographic indicators of this community (such as level of income, GNI, ethnicity, and recycling habit) could not be obtained.

Data collection commenced in 2010 and continued until 2011, when the only ISWM framework available at that time was that of Scheinberg A et al. (2010), which had no clear and effective methodology on how to evaluate the indicator values. However, recently, the methodology on how to use and build this framework became clearer after it was developed and called "*Wasteaware ISWM benchmark indicators"* (Wilson et al., 2012; Wilson et al., 2013a; Wilson et al., 2013b; Wilson et al., 2015). Therefore, the updated version of the ISWM framework (Wasteaware ISWM benchmark indicators) was used to assess Mina SWM. Due to this change, the values of solid waste density and moisture content (in the background information section) were not identified, but this had no effect on the overall framework (**Section 5-4**). In addition, the level of income and GNI were not estimated, as they were not applicable. Thus, whilst having the information regarding the detailed criteria and scoring before the practical fieldwork would have helped refine and target the research effort more effectively, the data that were gathered were generally fit for purpose.

Tables 4-6 to 4-9 show all the indicators and their criteria as considered in the latest version of the Wasteaware ISWM benchmark indicators for both the physical components of SWM and the governance aspects in addition to background information on the investigated city and its waste data (Wilson et al., 2015). After each criterion was given a score according to the user manual (Wilson et al., 2013b), all results of each indicator's criteria were normalised to a percentage and given a rating and colour (**Table 4-10**). Issues and decisions arising in determining scores when applying the framework are detailed in **Section 5-4**.

Table 4-6 Background information on the city, Wasteaware ISWM benchmark indicators. Adapted from Wilson et al. (2013b)

Element	No.	Indicator	Criteria	Score
Country income category	B1	World Bank income category		Low, lower middle, upper middle, or High
		Gross National Income (GNI) per capita		$ per capita
Population	B2	Total population of the city		Capita
Waste generation	B3	Total municipal solid waste generation		*t/year*
Date when indicators applied				

Table 4-7 Waste data, Wasteaware ISWM benchmark indicators. Adapted from Wilson et al. (2013b)

Element	No.	Indicator	Criteria	Score
Waste per capita	W1	$Kg.p^{-1}.d^{-1}$		
		$Kg.p^{-1}.d^{-1}$		
Waste composition	W2	Solid waste composition as % wt. of total waste generated	W2.1 Organic	%
			W2.2 Paper	%
			W2.3 Plastic	%
			W2.4 Metals	%
			W2.5 Solid waste density	%
			W2.6 Moisture content	%

Table 4-8 Physical components of Wasteaware ISWM benchmark indicators. Adapted from Wilson et al. (2013b)

Element	No.	Indicator	Criteria	Score
Waste collection (Public health)	1.1	Waste collection coverage		%
	1.2	Waste captured by the system		%
	1C	Quality of waste collection service	1C.1 Appearance of waste collection points	Very high incidence: 0 High incidence: 5 Medium incidence: 10 Low incidence: 15 Very low incidence: 20
			1C.2 Effectiveness of street cleaning	
			1C.3 Effectiveness of collection in low income districts	
			1C.4 Efficiency and effectiveness of waste transport	No compliance: 0 Low compliance: 5 Medium compliance: 10 Medium/High compliance: 15 High compliance: 20
			1C.5 Appropriateness of service planning and monitoring	
			1C.6 Health and safety of collection workers	
waste treatment and disposal (Environmental control)	2	Controlled treatment and disposal	Controlled treatment and disposal	Low: 0-49% Low/Medium: 50-74% Medium: 75-84% Medium/High: 85-94% High: 95-100%
	2E	Quality of environmental protection of waste treatment and disposal	2E.1 Degree of control over waste reception and general site management	No control: 0 Low level of control: 5 Medium level of control: 10 Medium/High level of control: 15 High level of control: 20
			2E.2 Degree of control over waste treatment and disposal	
			2E.3 Degree of monitoring and verification of environmental controls	No compliance: 0 Low compliance: 5 Medium compliance: 10 Medium/High compliance: 15 High compliance: 20
			2E.4 Efficiency of energy generation and use	
			2E.5 Degree of technical competence in the planning, management and operation of treatment and disposal	
			2E.6 Occupational health and safety	
Reduce, Reuse, Recycle (Resource Value – 3Rs)	3	Recycling rate	Percentage of total municipal solid waste generated that is recycled	Low: 0-9% Low/Medium: 10-24% Medium: 25-44% Medium/High: 45-64% High: > 65%
	3R	Quality of 3Rs – Reduce, reuse, recycle – provision	3R.1 Source separation of dry recyclables	• 0-1% clean source-separated materials: 0 • 1 – 25% clean source-separated materials: 5 • 26 – 65% clean source-separated materials: 10 • 65 – 95% clean source-separated materials: 15 • 96-100% clean source-separated materials: 20

			3R.2 Quality of recycled organic materials.	• No separation or quality control: 0 • Some separation to reduce contamination: 5 • Organic materials separated from other wastes in a treatment facility: 10 • All input material separated at source: 15 • All input material separated at source and meets a formal quality standard:20
			3R.3 Focus on the top levels of the waste hierarchy	No focus: 0 Low focus: 5 Medium focus: 10 Medium/High focus: 15 High level of focus: 20
			3R.4 Integration of the community and/or informal recycling sector (IRS) with the formal SWM system	
			3R.5 Environmental protection in recycling	No compliance: 0 Low compliance: 5 Medium compliance: 10 Medium/High compliance: 15 High compliance: 20
			3R.6 Occupational health and safety	

Table 4-9 Governance factors of Wasteaware ISWM benchmark indicators. Adapted from Wilson et al. (2013b)

Element	No.	Indicator	Criteria	Score
Inclusivity	4U	User inclusivity	4U.1 Equity of service provision	No compliance: 0 Low compliance: 5 Medium compliance: 10 Medium/High compliance: 15 High compliance: 20
			4U.2 The right to be heard	
			4U.3 Level of public involvement	
			4U.4 Public feedback mechanisms	
			4U.5 Public education and awareness	
			4U.6 Effectiveness in achieving behaviour change	
	4P	Provider inclusivity	4P.1 Legal framework	No compliance: 0 Low compliance: 5 Medium compliance: 10 Medium/High compliance: 15 High compliance: 20
			4P.2 Representation of the private sector	
			4P.3 Role of the ‘informal’ and community sector	
			4P.4 The balance of public vs. private sector interests in delivering services	
			4P.5 Bid processes	
Financial sustainability	5F	Financial sustainability	5F.1 Cost accounting	No compliance: 0 Low compliance: 5 Medium compliance: 10 Medium/High compliance: 15 High compliance: 20

			5F.2 Coverage of the available budget	• Covers 50% or less of current operating costs: 0 • Covers most current operating costs: 5 • Covers full operating and maintenance costs of current level of service: 10 • Covers full cost of providing current level of service including allowance for necessary improvements and costs of capital: 15 • Covers full cost of providing a high quality service including costs of capital: 20
			5F.3 Local cost recovery – from households	None: 0 Less than 25%: 5 25 – 49%: 10 50 - 74%: 15 75 - 100%: 20
			5F.4 Affordability of user charges	No compliance: 0 Low compliance: 5 Medium compliance: 10 Medium/High compliance: 15 High compliance: 20
			5F.5 Pricing of disposal	• No charge is made: 0 • Charged rate covers some costs of operation: 5 • Charged rate covers full operating and maintenance costs: 10 • Charged rate covers all operating costs, maintenance and capital costs: 15 • Charge rated covers all operating, maintenance and capital costs, and also sets aside savings for future closure and aftercare: 20
			5F.6 Access to capital for investment	No compliance: 0 Low compliance: 5 Medium compliance: 10 Medium/High compliance: 15 High compliance: 20
Sound institutions, proactive policies	6N	Adequacy of national SWM framework	6N.1 Legislation and regulations 6N.2 Strategy/Policy 6N.3 Guidelines and implementation procedures	No compliance: 0 Low compliance: 5 Medium compliance: 10 Medium/High compliance: 15 High compliance: 20
			6N.4 National institution responsible for implementing SWM policy	Low: 0 Low/Medium: 5 Medium: 10 Medium/High: 15 High: 20
			6N.5 Regulatory control / Enforcement 6N.6 Extended producer responsibility (EPR) or Product Stewardship (PS)	No compliance: 0 Low compliance: 5 Medium compliance: 10 Medium/High compliance: 15 High compliance: 20

	6L	Local institutional coherence	6L.1 Organizational structure/ coherence	No compliance: 0 Low compliance: 5 Medium compliance: 10 Medium/High compliance: 15 High compliance: 20
			6L.2 Institutional capacity	
			6L.3 City-wide SWM strategy & plan	
			6L.4 Availability and quality of SWM data	
			6L.5 Management, control and supervision of service delivery	
			6L.6 Inter-municipal (or regional) co-operation	

Table 4-10 The scoring and colour coding system for the Wasteaware ISWM benchmark indicators. Adapted from Wilson et al. (2013b)

Performance	**% Score**	**'Traffic light' code and colour**	
LOW	0 – 20%	Red	
LOW/MEDIUM	21 – 40%	Red/orange	
MEDIUM	41 – 60%	Orange	
MEDIUM/HIGH	61 – 80%	Orange/green	
HIGH	81 – 100%	Green	

Based on the collected data, the on-site observation, the interviews with officials from Mina authorities, and the judgment of the researcher, all of these criteria were adapted to the SWM system in Mina as much as possible (**Section 5-4**). Then, a comparison was made between the results of the investigated cities in (Wilson et al., 2012; Wilson et al., 2013a; Hickman, 2014) and the results of Wasteaware ISWM benchmark indicators of Mina (**Section 7-5-2**).

4-7 Camp Managers' Questionnaire and Assessment of Compactor Boxes

Surveys (questionnaires) are the best method to study the opinion of a big group of people (O'Leary, 2004). The camp managers' questionnaire aimed to formulate a general background from these managers about their camps in terms of services, SWM, their opinions about implementing the waste sorting project in their camps, and their assessment of the camp compactor boxes (part of **OBJ2**, **Section 3-2**).

Mina was divided into five zones according to the distribution of the Tawafa companies in order to fill this questionnaire. Five researcher's assistants (who were trained by the researcher especially in terms of ethics) were distributed among those zones. Each was asked to interview 30 camp managers selected randomly but within the Tawafa companies in their zone. Camp managers were firstly asked for their permission to be interviewed face-to-face, and then the researcher's assistants filled in each form according to each camp manager's answers.

A total of 103 forms were completed in full, with each one representing one camp. These 103 forms covered four Tawafa companies, namely, the South Asia Tawafa Company; South East Asia Tawafa Company; the Non-Arab African countries Tawafa Company; and the Turkey and the Muslims of Europe, the Americas, and Australia Tawafa Company.

Although the Arab Countries Tawafa Company and Saudi Arabia Pilgrims Tawafa Company were also covered, their results had to be discarded because they were unreliable. It was believed that these discarded forms were not filled in honestly, as many bizarre and untruthful answers were found; for instance, when the answer of the first question is no, questions 2 and 3 should be not answered, but on many occasions, answers were given to questions 2 and 3 despite the answer to question 1 being no. In addition, the Iran Tawafa Company was excluded because of the limited number of Iranian camps, which represent the same country, and the difficulty of finding a researcher's assistant who could speak their language.

4-7-1 Camps Manager Questionnaire Design

Table 4-11 Camp Managers' Questionnaire

The Question	***Answers***				
1- Do you provide meals for the pilgrims in your camp?	Yes		No	Sometimes	
If the answer is No, ignore questions 2 and 3					
2- Which meal do you provide?	breakfast	lunch	dinner	all of them	
3- What kind of meals do you provide in your camp?	hot meals	fast food	dry meals	what is available	not specific
4- Are there any places for selling food near to your camp?	yes	no		sometimes	don't know
5- What is the most common component in your camp's waste from your point of view?	organic waste	plastic	paper and cardboard	plastic films	aluminium cans
6- What do you do with the food residuals?	throw them away	reuse	give them to poor pilgrims		charity
7- Do you support the idea of deriving a benefit from your waste?	yes	no	don't know		
8- Are you going to support implementation of a waste sorting project in your camp?	yes	no	maybe		
9- If you found a buyer for the sorted waste in your camp, would you implement a sorting project in your camp?	yes	no	maybe		
10- What is the average cost for each pilgrim in your camp (SR)?	1000- 2000	2000-4000	4000-7000	7000-10000	> 10000
11- Where do you dispose of your camp's waste?	compactor box	special place inside the camp		outside the camp	
12- Do you have waste compactor box in your camp?	yes **(continue)**	no **(stop)**			
13- Do you think that one compactor box is enough for your camp?	yes	no		don't know	
14- Is it easy to reach the compactor box in your camp?	yes	no			
15- If the compacting box is broken, is maintenance work carried out as soon as is appropriate?	yes	no		don't know	
16- How many times a day is the waste collected and disposed of in the compacting box?	once	twice	three times	four times	more than four times

To achieve part of the second objective (**OBJ2**) of this research the questionnaire was designed with sixteen questions, and divided into three sections (**Table 4-11**). The first section asked about the general background of the Mina camps, such as food services and how much it cost for each pilgrim to stay in Mina (Questions 1, 2, 3, 4 and 10). The second part aimed to check the managers' opinions about implementing a waste sorting project in their camps (Questions 7, 8 and 9). The last section focussed on how they managed their waste as well as their assessment of the compactor boxes (Questions 5, 6, 11, 12, 13, 14, 15, and 16). Each interviewee was asked about which countries were being served in his camp and to which Tawafa Company the camp belonged.

4-8 Pilgrims' Questionnaire

The main goal of the pilgrims' questionnaire was to identity pilgrims' intention to sort their waste at source (optionally) during the Hajj to compare the results with the actual sorting percentages from the exemplar project (optional sorting project), which would then make it possible to identify the factors that affect the optional sorting intention and behaviour (parts of **OBJ2**, **OBJ3**, and **OBJ5 Section 3-2**). This was done to examine the relationship between the intention to sort and other factors that might be expected to affect the sorting intention. Many researchers have followed this method to study the factors that affect the public's intention, attitude and behaviour toward waste source separation and recycling (Kok and Siero, 1985; Vining et al., 1992; Schultz et al., 1995; Barr, 2007; Zhuang et al., 2008; Omran et al., 2009).

However, based on the literature review, the government should adopt a waste source separation strategy and force people by law to comply with it by making it compulsory

(**Section 2-2-5**). Thus, this questionnaire also aimed to study the pilgrims' intention to sort their waste at source if they were forced to do so by law.

A comparison was made between the pilgrims' optional and compulsory intentions to identify the differences and find the best responses. From this, an econometric model was formulated for the model with better results. Gujarati (2003) defined econometrics as '*the quantitative analysis of actual economic phenomena based on the concurrent development of theory and observation, related by appropriate methods of inference*'. The econometric model is used as a forecasting or predicting tool for the future (Maddala and Lahiri, 2009). Therefore, it was used in this research to predict the future positive intention of pilgrims to sort their waste at source based on the results of the questionnaire.

4-8-1 Pilgrims' Questionnaire Design

To meet the objective of this survey, a questionnaire was designed with 11 categorical enquiries as well as short definitions for waste sorting at source of generation and waste recycling. **Table 4-12** shows the questions and their multiple possible answers in this questionnaire.

This questionnaire was designed with the purpose of obtaining the pilgrims' intention to sort their waste at their camps in the future, in addition to the main factors that are expected to affect pilgrims' sorting intention (part of **OBJ3**). In addition, an overall assessment of the level of cleanliness in the Mina camps and streets was obtained by questions 7 and 8 (part of **OBJ2**).

Table 4-12 Pilgrims' questionnaire

Education level	1 illiterate	3 primary	5 Bachelor	7 PhD
	2 can read	4 high	6 Master	
What is your nationality	……………………..			
Questions	**Answers**			
	1	**2**	**3**	**4**
1- Do you eat in your Mina camp?	always	sometimes	rarely	
2- From where do you get your food?	from the camp catering	I buy it from outside the camp	both	
3- Did you hear anything about waste sorting and recycling?	yes	no		
4- Having read the definitions, do you think you will be able to sort your solid waste?	yes	no		
5- Do you sort your solid waste at your home in your country?	yes	no		
6-1 **If it were optional,** do you think you would sort your solid waste in your camp during the Hajj in Mina?	yes	maybe	no	
6-2 **If it were compulsory,** do you think you would sort your solid waste in your camp during the Hajj in Mina?	yes	maybe	no	
7- Are you satisfied about the level of cleanliness in Mina's steers during the Hajj?	very unsatisfied	unsatisfied	satisfied	very satisfied
8- Are you satisfied about the level of cleanliness in your Mina camp during the Hajj?	very unsatisfied	unsatisfied	satisfied	very satisfied

4-8-2 Pilgrims Questionnaire Distribution

This questionnaire was distributed in the same year (Hajj 2011) the exemplar project was implemented to ensure that the surrounding conditions of the actual sorting project and the data gathering by the questionnaire were fully comparable.

The filling in of the questionnaire was done by dividing Mina into ten zones according to the type of the pilgrims and the area where they were accommodated. After that, ten researcher's assistants (trained by the researcher especially in terms of ethics) were distributed among those zones according to the languages they could speak. Every assistant was responsible of filling in 100 forms of the pilgrims' questionnaire from randomly selected pilgrims (in their area). This was done by asking each selected pilgrim the survey questions face-to-face, and then the form was filled in by the researcher's assistant. This took place during the last three days of Mina to ensure that the pilgrims had received equal exposure to the background regarding waste in Mina as well as the situation inside their camps.

4-8-3 Pilgrims Questionnaire Statistical Analysis

When analysing qualitative data, the type of variable should be identified. In this form of questionnaire, there were two different types of category variables: nominal (just symbols that can differentiate various categories but that cannot be ordered) and ordinal (variables that can be ordered) (Marques de Sá, 2007). The nationality and questions 1 to 6 (1 and 2) were nominal variables whereas the level of education and questions 7 and 8 were ordinal variables. Marques de Sá (2007) stated that counts, mode, and frequencies are the proper descriptive statistics that can be obtained from the categorical variables (**Section 5-6-2**).

After the results had been gathered from the pilgrims' responses, an econometric model was formulated for the model with higher pseudo R^2 (which measures the model's goodness of fit) to predict the pilgrims' future positive intention toward recycling. To do so, all questions in this questionnaire were divided into dependent and independent variables. The dependent variables were questions Q6-1 (optional sorting) and Q6-2 (compulsory sorting) whereas the independent variables were the other questions in the questionnaire, which represent the factors expected to have an influence on sorting intention. These factors were level of education, nationality (ethnicity), where and how the pilgrims get their food, the pilgrims' solid waste source separation background and practice, and their degree of satisfaction with the levels of cleanliness in Mina's streets as well as in their own camps. These factors were chosen based on information derived from the literature review (**Section 2-3-4**), time and place factors, limitations, and anecdotal evidence.

This is the first time such factors have been obtained regarding pilgrims' recycling intention during the Hajj; Barber et al. (2014) stated that event visitors have never been studied before in terms of their intention and opinions regarding recycling and waste management. Therefore, this research assumed that these factors were the most important factors that affect pilgrims' recycling intention. However, there might be more factors, and these could be identified in possible future research.

However, age and level of income were not considered in this survey. This was because this questionnaire was filled in by ten interviewers (trained researcher's assistants) using the face-to-face survey strategy, and Denscombe (2010) reported that asking people about sensitive issues (such as level of income) in a face-to-face survey may cause them to give inaccurate or incorrect answers. Secondly, in many studies, these two factors were not statistically significantly related to sorting behaviour; for instance, Schultz et al. (1995) concluded that age does not affect people's intention to sort their waste while Kok and Siero (1985) and Nixon and Saphores (2009) reported that there is no relationship between level of income and people's sorting intention (**Section 2-3-4**).

To build the econometric model, the statistically significant effect of the independent variables on the dependent variable needed to be obtained by performing a regression.

Regression is defined as a statistical process for obtaining the relationships between variables (Field, 2009). As the dependent variables (Q6-1 and 6-2) are nominal variables with three levels of response, a statistical multinomial logistic regression was done twice (initially for Q6-1 and secondly for Q6-2 both as dependent variables) using the Statistical Package for the Social Sciences (SPSS, 2011). The remaining questions, in addition to the Tawafa company groups and level of education, were added to the model as independent variables that possibly could affect the pilgrims’ sorting intention. Thus, to examine if the relationship between the dependent and independent variables was statistically significant, the p-value of each independent variable was tested at a 95% level of confidence.

To enhance such models, Lawal (2014) concluded that using the geo-demographic groups improves and enriches the SWM plan and future development. However, in the Hajj, the geo-demographic groups were not applicable, whereas socio-demographic indicators for each country were available; and as the extended TPB (**Section 2-3-4**) showed, some demographic factors affect waste sorting and recycling intention and behaviour. In addition, Troschinetz and Mihelcic (2009b) indicated that some socio-demographic factors (such as level of education, and level of income) affect the level of recycling in developing countries (where most of the pilgrims come from). Thus, some socio-demographic indicators for each country were added to the models. These indicators were chosen based on the relationship to the subject and availability to all countries included in the pilgrims' questionnaire:

- Gross Domestic Product per capita (GDP per capita): power of purchasing based on parity divided by population (CIA, 2013). This indicator can reflect the pilgrims’ level of income.

- Human Development Index (HDI): includes education, health care and income (Hastings, 2009). This indicator (also) refers to the pilgrims' level of income, but it is combined with their social level.

- Gross National Income (GNI per capita): the value of the US dollar of a country's final income annually, which represents the average income of the inhabitants in the country (World Bank, 2013). Again, this indicator represents the pilgrims' level of income but using a different method from the previous two.

- Level of income of the whole country, which is calculated by the World Bank for each country based on its GNI per capita (World Bank, 2013).

- Waste generation rate per capita (references for the figure for each country are represented in **Table 5-18**). This indicator was used to check if there was any relationship between the quantity of waste generated by each pilgrim at his home and his/her recycling intention.

- Environmental Performance Index (EPI) (Emerson et al., 2012): this assesses environmental health (air quality, health impact, and water and sanitation) and ecosystem vitality (water resources, forest, agriculture, fisheries, biodiversity and habitat, and climate change and energy) (Emerson et al., 2012). This indicator has many aspects of life quality, which may affect the intention to participate in recycling.

However, at the time of data analysis, there was insufficient information to include the Quality of Life Index as an extra indicator. Furthermore, recycling rates were not added as an explanatory factor because of the lack of data even at the most comprehensive reference about waste, that is, the Waste Atlas (Koukosia et al., 2013). In addition, for many countries, recycling is performed through the informal sector where the percentage of recycling is sometimes unknown.

The indicators for all the included countries were tested (in formulating the econometric model) both separately and together, but the highly correlated indicators at 0.8 (such as GNI, GDP and HDI) were not tested together in one model because of the potential similarity between them. The value of pseudo R^2 was the main reason for choosing the indicators used in the model.

As SPSS gives three values for pseudo R^2 (Cox and Snell, Nagelkerke, and McFadden), many researchers have found that McFadden's pseudo R^2 is the best method to measure a model's goodness of fit (Veall and Zimmermann, 1996; Long and Freese, 2006). Furthermore, Allison (2014) recommended using McFadden's pseudo R^2 rather than that of Cox and Snell in a multinomial regression. In addition, a high value for McFadden's pseudo R^2 is hard to obtain, especially a value of 1, as it is defined as 1 minus the log likelihood ratio (Hu et al., 2006). Based on this, Mcfadden (1979) stated that values between 0.2 - 0.4 for McFadden's pseudo R^2 would indicate that the model fits excellently.

The chosen socio-demographic indicators for each of the 60 countries included in the pilgrims' questionnaire were GDP per capita, EPI, and waste generation rate per capita. These were added to the model as covariate factors to explore whether there was any statistically significant relation between the intention to sort at source (Q6-1 and Q6-2) and these indicators at a 95% level of confidence (**Section 5-6**).

To formulate the econometric model for the model with the highest McFadden pseudo R^2 value, a logit model was used rather than a probit model. This is because the difference between the logit and the probit model is very small, and the logit model is preferred by many researchers because of its comparative mathematical simplicity (Gujarati, 2003; Maddala and Lahiri, 2009). **Equation 4-4** shows the formula used to estimate the logit model (Gujarati, 2003).

$$P_i = \frac{1}{1+e^{-Z_i}} \quad \textbf{Equation 4-4}$$

Where: P_i = probability of pilgrims' positive sorting intention, ranging between 0 and 1.

Z_i = ranges from $-\infty$ to $+\infty$, and its value is shown in **Equation 4-5.**

$$Z_i = \beta_1 + \beta_2 X_i \quad \textbf{Equation 4-5}$$

Where: β_1 = the intercept, β_2 = slope coefficients, X_i = the independent variables

4-9 Exemplar Project (Sorting Project)

The exemplar project aimed to verify that the potential solutions can be transferred to a practical project during mega events, such as the Hajj (**OBJ4**, **Section 3-2**). Many prestigious events, such as the Olympics and music festivals, have seen the need to test and demonstrate what can be done through exemplar projects. Therefore, pilgrims' ability to sort their waste at source was tested by applying this exemplar project, which demonstrated whether pilgrims' waste disposal behaviour can be changed and if they can adapt faster than the Mina authorities believe they can.

In addition to its potential value in stimulating much needed improvements in the long term, such a project would enable the researcher to compare the stated views of stakeholders (pilgrims' intention to sort) with what actually happens in practice (pilgrims' sorting behaviour) to estimate the predictive accuracy of the pilgrims' intention (**OBJ5**, **Section 3-2**). Furthermore, it provides an opportunity to establish links with those in the recycling sector, an essential partner if Mina is to progress to a more recycling-orientated waste management system in the future. In addition, the exemplar project was predicted to play an important role in stimulating the Mina authorities to progress toward a more resource-saving and sustainable waste management system.

Exemplar projects do not change the current system, but they stimulate the process of identifying and implementing practical solutions. As the management of waste sorting and recycling cannot be separated from the whole SWM issue in Mina, the success of this project was expected to be limited, and subsequently, the quantity of sorted waste was predicted to be low. This project tested the pilgrims' ability to change their behaviour regarding waste disposal and their reactions towards a sorting project. Essentially, it could serve as a motivation for developing a more sustainable waste management system in the medium to long term.

4-9-1 Exemplar Project Planning

The main plan was to implement the waste sorting at source in a number of different camps in Mina during the Hajj, which would give an idea about the main factors that affect sorting behaviour. Since the system was designed to be implemented in the three camps in similar conditions (same sorted material, same system, and same maintenance), the main difference between these three camps was in the pilgrims' (the individuals) characteristics (**Section 2-3**). Thus, three different factors, which were related to the pilgrims, were selected to facilitate the process of choosing the camps, based on information derived from the literature review regarding the main factors that affect individuals' recycling behaviour (**Section 2-3-4**). These factors were the level of education, the living standards, and the waste sorting background and habit. These factors allowed the researcher to compare the behaviours of pilgrims with different backgrounds, for instance, waste sorting by pilgrims with or without a background of waste sorting, as well as comparing the pilgrims' education, understanding, and culture.

Based on the information derived from the literature review regarding how a sorting project should be designed in busy areas and mega events (**Sections 2-3** and **2-6**), this project aimed to identify one of the main waste components in Mina camps to be sorted at source by the pilgrims. As found in the study of the waste composition (**Section 5-3**), there are three main waste categories in the Mina camps: organic waste (29.28 ± 4.1%), plastic (27.98± 3.47%), and paper and cardboard (24.74± 4.52%). As can be seen from the camp managers' questionnaire (**Section 5-5**), organic waste and plastic were considered the most abundant components in the camp waste (from the managers' point of view).

However, there is no benefit to be derived from separating out the organic waste because of the lack of composting and waste-to-energy facilities in this region of Saudi Arabia (**Section 1-6**). Furthermore, this research suggested that it is easier for pilgrims to identify and sort plastic than paper. In addition, plastic waste can be sold at much higher prices than can paper waste, which should motivate investors to participate in this project. Thus, the pilgrims were asked to sort plastic (plastic bottles and other plastic) at source, but they were not asked to sort plastic films. This was, among other reasons, to avoid contamination with food, as the pilgrims usually use plastic film as a mat on which to place food.

Although there was a limited scheme in terms of recycling potential, the pilgrims were not asked to sort all of the recyclable waste or plastic and paper together because of the possible confusion they might experience as well as the limited storage space available. In addition, the level of the sorted waste contamination could be more easily identified if the pilgrims sorted just their plastic waste.

Based on all these facts and the research limitations, this research planned to apply this project in three camps from three different Tawafa companies. The pilgrims in these three camps would differ in terms of education, social level, and sorting background and habit (**Figure 4-6**). These camps were as follows:

1- Egyptian pilgrims' camp (VIP services) from the Arabic Countries Tawafa Company: the pilgrims were well educated with middle to high living standards but their sorting habit were unknown as Egyptians are not asked formally to sort their waste at home, but they might do it to sell the sorted waste informally (Wilson et al., 2006).

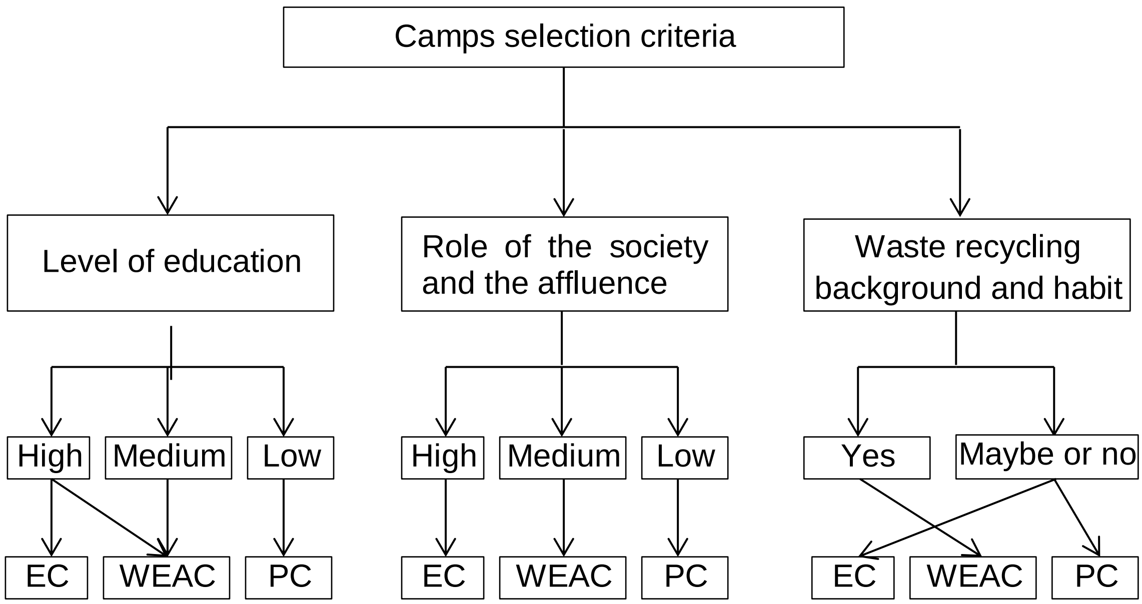

Figure 4-6 The three camps' selection criteria in the exemplar project, where EC refers to Egyptian camp, WEAC: Western European and Australian camp, and PC: Pakistani camp

2- Western European and Australian Pilgrims' camp from Turkey and Muslims of Europe, the Americas and Australia Tawafa Company: the pilgrims were considered as having medium living standards. In addition, the pilgrims came from countries that impose waste sorting in the home, which means that they should have had sorting habit. However, it was expected that some of them would not practise waste sorting at home, like people who live in apartments in the UK (Kuss-Tenzer et al., 2006).

3- Pakistani pilgrims' camp from South Asia Tawafa Company: the pilgrims were not well educated and had poor living standards. In terms of their waste sorting habit, it was believed that their situation was similar to that of the Egyptian pilgrims, in that some of them might have recycling habit.

4-9-2 System Design and Implementation

The design of the sorting system was based on information derived from the literature review on designing a recycling facility in a crowded area (**Sections 2-3-1**) taking into account the time and place limitations. The sorting bins and their iconography were designed taking into consideration the specifications mentioned previously in **Section 2-3-1** as shown in **Figure 4-7**.

It is believed that to increase individuals' positive attitude toward recycling and sorting at source (**Section 2-3-4**), there must be educational programmes and information campaigns about the importance to the environment and to resources of waste source separation (Thogersen, 1994). Furthermore, Zhuang et al. (2008) found that there is a positive relationship between source sorting and regular publicity while Nixon and Saphores (2009) suggested that it is effective to use printed sources (such as posters and newspapers) to enhance recycling and sorting information. Thus, 30 posters and banners were distributed among the three camps, which showed the pilgrims how and why they should sort out their plastic waste, as **Figure 4-8** illustrates.

Figure 4-7 The design of a sorting bin and its iconography

In addition, to reinforce the impact of the signage and explain in more detail the benefits of and reasons for recycling and environmental protection, 10,000 copies of a brochure were distributed among the pilgrims in their own languages (Arabic, English (**Figure 4-9**) and Urdu). It contained the following:

- the main goal of the project
- recommended mechanism for the success of the project
- the project organizer
- a summary of the Hajj deeds (motivating pilgrims to keep the brochure)

Figure 4-8 Posters and banners distributed in the three camps as a part of an educational campaign for the exemplar project

Figure 4-9 The English version of the exemplar project brochure

The implementation of this project started on 4/11/2011 with the distribution of 35 to 50 green bins with blue waste bags in the three camps (according to the camp area and number of pilgrims). These bins were dispersed beside each general waste bin in the corridors outside the tents all over the camp (**Figure 4-10**). Then between 6-8/11/2011 (two and half days), the pilgrims were asked to put their plastic waste in the green bins and their other waste in the second bin.

The volume of each green bin was 80 litres (0.08 m^3). Thus, the daily provided volume (PV) in each camp was calculated based on **Equation 4-6.** According to WRAP (2009), the mean density of uncompressed mixed plastic (with no plastic film) for a similar size of the green bin is 21 $kg.m^{-3}$. Therefore, the maximum daily weight that could be sorted in the green bins (MSP) was estimated based on **Equation 4-7.**

$$\text{PV} = \text{bin volume} \times \text{No. of bins} \times \text{No. of times bins were emptied} \qquad \textbf{Equation 4-6}$$

Where: PV = daily provided volume for sorting

$$\text{MSP} = \text{PV} \times \text{waste density} \qquad \textbf{Equation 4-7}$$

Where: MSP = maximum daily weight that can be sorted in the green bins

Waste density = 21 $kg.m^{-3}$ (WRAP, 2009).

As mentioned in **Section 2-3-4**, to make people sort their waste, a motivation should be given to the participants in waste separation projects. In this study, to achieve this goal and make the pilgrims use this system (sort their waste), they were told that the benefits from this project would go directly to the charity, and the project was implemented under the title of *"Give it to Someone in Charity Instead of Throwing it Out"*. This meant that the profit from the sold sorted plastic would go to charity.

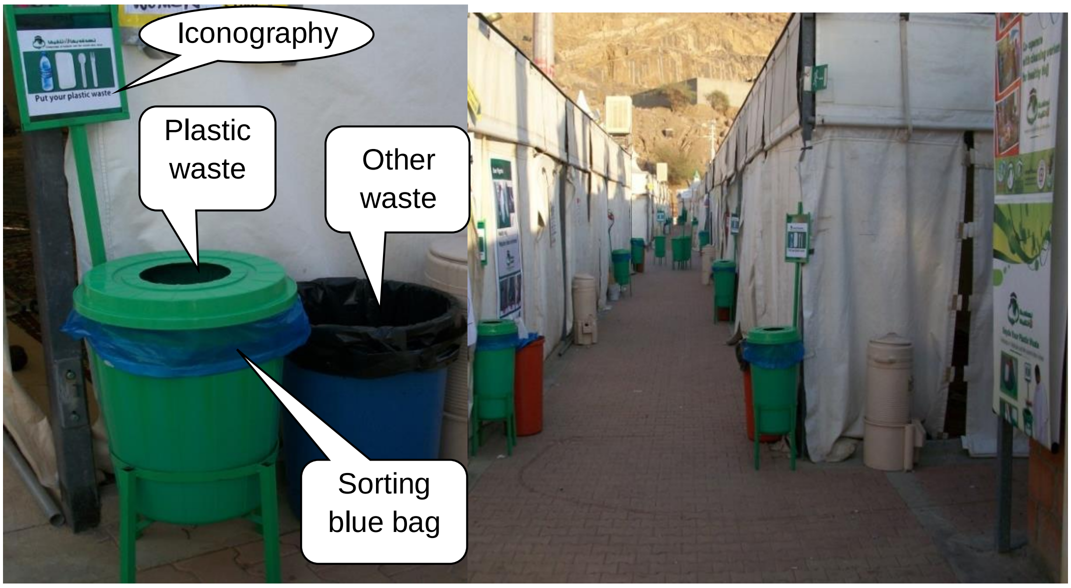

Figure 4-10 The distribution of green sorting bin beside the general waste bin for the exemplar project

In order to make this project happen, the researcher lobbied and acquired funds and legal support from five different organizations:

1- Custodian of the Two Holy Mosques Institute of Hajj Research

2- Haji and Mu'tamer's Gift Charity Association

3- Ma'aden Gold Mining Company

4- Environmentalist for Studying and Consulting

5- Global for Food Hygiene and Safety

4-9-3 System Operation and Performance

To understand the reaction of the pilgrims to this project, a systematic observation method was used. In this method, it is not recommended that the researcher be the main observer; instead, observation is done through other individuals (research assistants) using an observation schedule or checklist (Denscombe, 2010). This method minimises the chance of the preconceived ideas and personal goals of the researcher influencing what is observed and ensures objective observations (O'Leary, 2004). Thus, ten supervisors (research assistants) were distributed among the three camps to monitor the behaviour of the pilgrims toward the sorting project. They were also responsible for improving the level of the project performance and for raising the pilgrims' awareness about the importance of this project. These supervisors received three days of training about their duties before the Hajj. Each of them was chosen according to the following criteria:

- the ability to speak the language or the languages of the pilgrim in the camp
- the speaking style and the ability of persuasion

- understanding of and interest in the project
- ability to collect all sorted waste and change the sorting bins bags at specific times

This project was implemented while each camp was at full capacity, that is, in two and quarter days only out of the five Mina days. That was because all pilgrims should be in the camp in this time but do not need to be in camp for the rest of the Mina days. In other words, pilgrims' presence in Mina is voluntary the first day, the first half of the second day, the last quarter of the fourth day and the fifth day but is compulsory for the remainder of the second day, all of the third day and the remainder of the fourth day.

However, the project was partially tested on the first day of Mina days to avoid any problems and make sure it would run as smoothly as possible. Because it was a test, the sorted waste was not collected, and the sorting waste bins had been emptied and cleaned by the end of the day to be ready for the real start of the project. One of the major problems the test identified was related to the general waste bins: the camps' cleaning workers changed the location of the bins while they were cleaning them. This caused the pilgrims to dispose of their general waste in the sorting bin because it was closer in some cases. To avoid this problem, the camp staff were asked to keep their bins in the same place beside the sorting bins, and this was also one of the supervisors' duties. Thus, the project was started on the afternoon of the second day 6/11/2011 until 18:00 of 8/11/2011, that is, the fourth day of the Mina days.

The agreed percentage of plastic in the uncontaminated bags was 90% (10% contamination), but the non-plastic waste in these bags was removed during the collection process and disposed of in the compactor box (as much as possible). Although there were many contaminated sorted waste bags (blue bags), it was almost impossible to study the composition of the waste because of the time and place limitations. Therefore, these bags were disposed of with the general waste in the compactor box, but the percentage of contaminated and uncontaminated bags was obtained from the supervisors' notes.

One of the supervisors' most important jobs was to record in their notes their observations and discussions with the pilgrims. Furthermore, after the end of the Hajj, camp managers were interviewed informally to obtain information about pilgrims in each camp as well as managers' feedback about the project. These notes and interviews were very important for identifying the main factors that affected this project or in other words, the factors that influenced the pilgrims' sorting behaviour.

4-9-4 Waste Composition

To estimate the percentage of the sorted plastic out of the total amount of plastic generated by the pilgrims in each camp, waste composition was required. To obtain the solid waste composition in each of the three camps, the waste characterization method mentioned in **Section 4-5** was followed to acquire a sample from each camp compactor box and find the main waste components. However, in this time, the safety factor was increased to 10 – 20 bags in each sample to ensure that the sample weight was between 91 to 136 kg (**Section 4-5**).

4-9-5 Informal Interviews with the Three Camps Managers

Turner (2010) reported that informal interviews allow the researcher to identify the interviewee's concerns, opinions, and new ideas by asking flexible and original questions. The interview is usually takes the form of a conversation about key information with an individual who represents a group of people (O'Leary, 2004). Thus, interviews with the managers of the three camps were conducted before and after the Hajj. These interviews were based on prepared questions, but in the form of a conversation:

1- background about the camp and pilgrims
2- type of services provided to the pilgrims
3- managers' opinions about the present SWM in their camps and their assessment of the compactor boxes
4- feedback about the sorting project as well as camp managers' thoughts about the project before and after implementing it as well as suggestions for the future.

4-10 A Comparison between Pilgrims' Recycling Intention and Behaviour

The comparison between the pilgrims' recycling intention and actual behaviour was made based on Ajzen and Fishbein (1980) claim that "*intentions should always predict behavior, provided that the measure of intention corresponds to the behavioral criterion and that the intention has not changed prior to performance of the behavior*". The aim of this comparison was to identify the predictive accuracy of the pilgrims' stated sorting intention. This was done through comparing the pilgrims' intention to sort their waste at source optionally (questionnaire) and the results obtained from the exemplar project (optional sorting project) as shown in **Equation 4-8**.

$$\text{Predictive accuracy of the stated intention (PASI)} = \frac{\text{Actual behviour}}{\text{Stated intention}} \times 100 \qquad \textbf{Equation 4-8}$$

Many researchers believe that the relationship between this type of intention (behavioural intention) and actual behaviour is controversial because, sometimes, stated intention are poor predictors of future behaviour (Manski, 1990). Furthermore, it is reported that this relationship depends on whether the intention and behaviour were estimated for the same sample or for different individuals within the same community (Chandon et al., 2005). Therefore, in this research to avoid self-generated validity phenomena, which is defined as enhance the relationship between individuals' intention and behaviour caused by measuring their intention (Feldman and Lynch, 1988), the individuals whose behaviours were monitored were not the same as those who were interviewed in the survey.

However, in the exemplar project, it was impossible to count the number of pilgrims in each camp who sorted their waste as hundreds or maybe thousands of pilgrims in each camp were using the same system. This prevented a direct comparison being made between the percentage of pilgrims who intended to sort their waste (questionnaire) and the percentage of the participants in the sorting project; consequently, as the participants were not identified, their recycling habits were unknown. Therefore, both samples (in the questionnaire and the exemplar project) of each group of nationalities were considered as representative of the whole population of the same group. Thus, the Egyptian pilgrims who were interviewed in the questionnaire and the Egyptian pilgrims who participated in the exemplar project were representatives of the entire population of the Egyptian pilgrims' community

However, this comparison was made between the actual behaviour of waste sorting with the predicted future behaviour based on two important assumptions: all pilgrims who intended to participate in recycling would sort all of their plastic waste, and pilgrims who participated in the exemplar project sorted all of their plastic waste and the remaining pilgrims did not participate at all. Through the second assumption, the percentage of participants in the actual behaviour was the same to the percentage of sorted plastic. Therefore, the estimated percentage of participants was compared with the percentage of pilgrims who were expected to participate in the recycling project based on their stated intention, which gave the level of predictive accuracy (**Equation 4-8**).

To predict the future sorting behaviour from the stated intention, the answers of the optional waste sorting question (Question 6-1, **Table 4-12**) were divided into three groups, and then the predicated future behaviour was calculated for each group. The first group contained pilgrims with a strong intention to sort their waste at their camps (pilgrims who answered "Yes"), the second group was the weak intention group (pilgrims whose responses to this question were "Maybe"), and the third group was the group with no intention of recycling (pilgrims who said "No"). Fujii and Gärling (2003) demonstrated that to predict future behaviour from a stated intention, people with the habit should be differentiated from people without the habit (because people without the habit are asked to change their current behaviour and acquire a new habit), which is essential in determining the possibility of transferring the stated intention into actual behaviour. Very few studies have addressed this issue of comparing intention, behaviour, and habit. In fact, Fujii and Gärling (2003) is the only research (case study) found that provided actual percentages for the three previous groups based on the presence of the habit.

Fujii and Gärling (2003) concluded that if people have the habit, it can be expected that 60% - 70% of their strong stated intention will be transferred to an actual behaviour whereas in the case of a weak intention, this will happen to 30% - 40% of them, while about 5% of people with no intention are expected to perform the behaviour; if people do not have the habit, these figure decrease by 20% - 30%. Based on the average of these figures, the predicted future behaviour for the three intention groups (in this research) was calculated based on two habit scenarios. In the first scenario, the expected future sorting behaviour was 65%, 35% and 5% of the stated strong, weak, and no intention values respectively, whereas in the second scenario, these figures decreased to 49%, 26% and 3.8% respectively. After the results were added together, the predicted positive sorting behaviour was calculated for the two habit scenarios, for the nationalities of three camps and for the overall pilgrims. Then, the results were normalised based on the computed percentage of pilgrims with and without recycling habit for each nationalities group from pilgrims' responses to question 5 in pilgrims' questionnaire (**Section 5-6-1**).

4-11 Research Limitations

Key limitations in this research can be summarized as follows:

1- The fieldwork had to be done only during three to five days in each year (Mina days).
2- There was difficulty communicating with pilgrims because of multilingualism.
3- There were difficulties in data collection and interviewing the officials from the Mina authorities.
4- There was a lack of substantial relevant SWM research for Mina.
5- There was very limited data about SMW in Mina.
6- The Mina authorities did not agree to support the sorting project in a public manner, though this would have given it more authority with camp managers, workers, and pilgrims. However the researcher had to meet many officials to obtain the necessary approvals for implementing this project and, although time consuming, all the necessary permissions were granted in time for the project plan to be implemented.

CHAPTER 5

RESULTS ON CURRENT SITUATION OF SWM IN MINA

5-1 Introduction

This chapter presents the first part of the research results that relate to the first period of data collection (fieldwork) and a part from the second period (pilgrims' questionnaire), in line with the objectives **OBJ1**, **OBJ2** and **OBJ3** and according to the methods detailed in **Sections 4-3 to 4-8**. Specifically, in this chapter, the results for the adapted Wasteaware ISWM benchmark indicators for the Mina SWM system (**Section 5-4**); and for the camp managers' questionnaire (**Section 5-5**) and the pilgrims' questionnaire (**Section 5-6**) are presented.

5-2 Estimation of Solid Waste Quantity in Mina Streets

In total, 270 samples were taken in Alkaif Street and 384 samples in Souq Alarab Street, as shown in **Tables A2, A3-a and A3-b** in **Appendix A**. As mentioned in the methodology (**Section 4-4**), waste usually accumulated at the edges of the street because of the different sources of waste, as mentioned in **Section 1-7-1** while the quantity of waste in the centre was usually almost zero (**Figure 5-1**). In the part B - **Figure 5-1**, the big pile of waste was thrown from adjoining camp into the street by the camp cleaning workers.

Figure 5-1 Two examples for waste accumulated at the edges of the Mina streets whereas in the centre, there was almost no waste in the two examples

5-2-1 Estimation of Total Waste in Alkaif Street

Table 5-1 shows the average weight of waste for the three days based on the three time intervals for each place while **Table 5-2** shows the total quantity of all samples collected from Alkaif Street and the averages as well as the total and average per each time interval.

Table 5-1 The total and average waste quantities in Alkaif Street for each time interval

	First place			**Second place**			**Third place**			**Fourth place**			**Fifth place**		
	L	*C*	*R*	*L*	*C*	*R*	*L*	*C*	*R*	*L*	*C*	*R*	*L*	*C*	*R*
	Time interval = 00:00 to 07:00														
Total	4	0	10.8	8.5	0	8.4	10.7	0	0	6.5	0	0	0	0	0
Avg.	1	0	2.7	2.1	0	2.1	2.7	0	0	1.6	0	0	0	0	0
Time interval = 07:00 to 16:00															
Total	18.8	0.1	18.1	13.3	0	16.6	22.5	0	10.7	8.2	2	3.9	1	0	2.7
Avg.	2.4	0	2.3	1.7	0	2.1	2.8	0	1.3	1.0	0.3	0.5	0.1	0	0.3
Time interval = 16:00 to 00:00															
Total	26.1	1.8	20.9	6.1	0.1	12.1	5.8	0.1	8.1	9.5	0	5.6	1.9	0.3	1
Avg.	4.4	0.3	3.5	1.0	0.0	2.0	1.0	0.0	1.4	1.6	0.0	0.9	0.3	0.1	0.2

Table 5-2 Average weight of waste samples for each time interval, from left, centre, and right of Alkaif Street

	Left	**Centre**	**Right**
Time interval = 00:00 to 07:00			
No. of samples	20	20	20
Total weight of all samples (kg)	29.7	0	19.2
The average (kg.m^{-2})	1.5	0	1
Time interval = 07:00 to 16:00			
No. of samples	40	40	40
Total weight of all samples (kg)	63.8	2.1	52
The average (kg.m^{-2})	1.6	0.1	1.3
Time interval = 16:00 to 00:00			
No. of samples	30	30	30
Total weight of all samples (kg)	49.4	2.3	47.7
The average (kg.m^{-2})	1.6	0.1	1.6
Total for all intervals			
No. of samples	90	90	90
Total weight of all samples (kg)	142.9	4.4	118.9
The average (kg.m^{-2})	1.59	0.05	1.32

Figure 5-2 VIP Saudi pilgrims' entrance, where the street was cleaned by the camp cleaning workers, which helped in the cleaning process

One of the main problem affected this process was the illegal pilgrims, because they were sitting in the sampling collection places. In addition, it was sometimes very crowded, so the samples collector had to wait until the crowd had diminished. In contrast, sometimes the cleaning workers of the VIP camps were cleaning outside the compound at the entrance to give their compound a good image (**Figure 5-2**).

As mentioned in **Section 4-4**, there are two assumptions for the estimation of waste quantities: one considers an area of 1 m and the other considers an area 2 m from the edge. The rest of the street is the width of the centre.

1- Width of 1 m from the edges

The width of Alkaif Street = 12 m

The length of the selected part of Alkaif Street = 470 m

Based on the average weight of the waste estimated in **Table 5-2** for all time intervals, total weight of the waste was estimated in the left edge (WL), right edge (WR) and the centre of the street (WCE) as follows:

WL = 1.59 * 1 * 470 = 747.3 kg

WCE = 0.05 * (12-1-1) * 470 = 235 kg

WR = 1.32 * 1 * 470 = 620.4 kg

The total weight of the waste in Alkaif Street at any given time

= 747.3 + 235+ 620.4 = 1602.7 kg

2- Width of 2 m from the edges

WL = 1.59 * 2 * 470 = 1494.6 kg

WCE = 0.05 * (12-2-2) * 470 = 188 kg

WR = 1.32 * 2 * 470 = 1240.8 kg

The total weight of the waste in Alkaif Street at any given time

= 1494.6 + 188 + 1240.8 = 2923.4 kg

Figure 5-3 illustrates the average estimated quantity of solid waste in Alkaif Street in Mina during the Hajj, which showed how waste was distributed in this street based on the assumption of waste accumulating at the street edges.

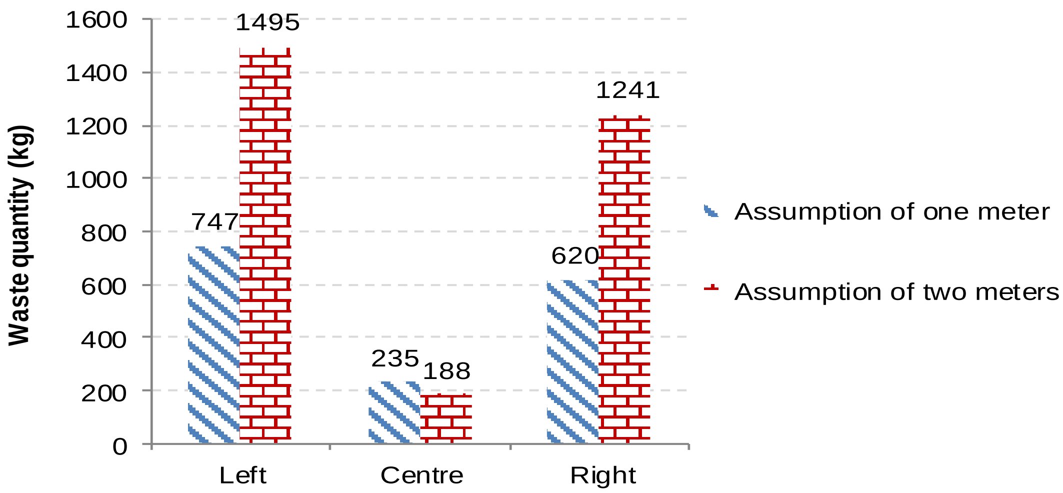

Figure 5-3 The estimated waste quantity for WL, WR, and WCE in Alkaif Street for both assumptions

5-2-2 Estimation of the Total Waste in Souq Alarab Street

Table 5-3 shows the average weight of waste for the three days based on the three time intervals for each place while **Table 5-4** shows the total quantity of all samples collected from Souq Alarab Street and their averages as well as the total and average for each time interval.

Table 5-3 The total and average waste quantities in Souq Alarab Street for each time interval

	First place			Second place			Third place			Fourth place			Fifth place			Sixth place			Seventh place			Eighth place		
	L	*C*	*R*	*L*	*C*	*R*	*L*	*C*	*R*	*L*	*C*	*R*	*L*	*C*	*R*	*L*	*C*	*R*	*L*	*C*	*R*	*L*	*C*	*R*
	Time interval = 00:00 to 07:00																							
Total	4.5	0.5	4	4	1	9	6	0	20	1	2	16	4.5	0	0	1.5	2	4	0	0	4	21	0	11.5
Avg.	1.1	0.1	1	1	0.3	2.3	1.5	0	5	0.3	0.5	4	1.1	0	0	0.4	0.5	1	0	0	1	5.3	0	2.9
Time interval = 07:00 to 16:00																								
Total	15	0	4.5	16.8	0	12.5	7	0	23.5	17	0.3	12.3	7.8	0	7.5	9.3	0	6	13.5	0	25	19.5	0	13
Avg.	2.5	0	0.8	2.8	0	2.1	1.2	0	3.9	2.8	0	2	1.3	0	1.3	1.5	0	1	2.3	0	4.2	3.3	0	2.2
Time interval = 16:00 to 00:00																								
Total	26	0.5	22.5	18.3	0	16.5	25.5	0	26.5	9	0	15.5	6	0	10	21	0	7	0	0	0	12	0	24
Avg.	4.3	0.1	3.8	3	0	2.8	4.3	0	4.4	1.5	0	2.6	1	0	1.7	3.5	0	1.2	0	0	0	2	0	4

Table 5-4 Average weight of waste samples for each time interval, from left, centre, and right of Souq Alarab Street

	Left	**Centre**	**Right**
Time interval = 00:00 to 07:00			
No. of samples	32	32	32
Total weight of all samples (kg)	42.5	5.5	68.5
The average (kg.m^{-2})	1.3	0.2	2.1
Time interval = 07:00 to 16:00			
No. of samples	48	48	48
Total weight of all samples (kg)	105.8	0.3	104.3
The average (kg.m^{-2})	2.2	0	2.2
Time interval = 16:00 to 00:00			
No. of samples	48	48	48
Total weight of all samples (kg)	117.8	0.5	122
The average (kg.m^{-2})	2.5	0	2.5
Total for all intervals			
No. of samples	128	128	128
Total weight of all samples (kg)	266	6.3	294.8
The average (kg.m^{-2})	2.08	0.05	2.3

To estimate the quantity of waste in Souq Alarab Street according to the average weight of the waste estimated in **Table 5-4** for all time intervals, the following calculations were performed:

1- Width of 1 m from the edges

The width of the selected part of Souq Alarab street = 12 m

The length of Souq Alarab Street = 1300 m

WL = 2.08 * 1 * 1300 = 2704 kg

WCE = 0.05 * (12-1-1) * 1300 = 650 kg

WR = 2.3 * 1 * 1300 = 2990 kg

The total weight of the waste in Souq Alarab Street at any given time

= 2704 + 650 + 2990 = 6344 kg

2- Width of 2 m from the edges

WL = 2.08 * 2 * 1300 = 5408 kg

WCE = 0.05 * (12-2-2) * 1300 = 520 kg

WR = 2.3 * 2 * 1300 = 5980 kg

The total weight of the waste in Souq Alarab Street at any given time

= 5408 + 520 + 5980 = 11908 kg

Figure 5-4 shows the average estimated waste quantity in Souq Alarab Street, which illustrates the distribution of waste in this street based on the assumption of waste accumulated at the street edges.

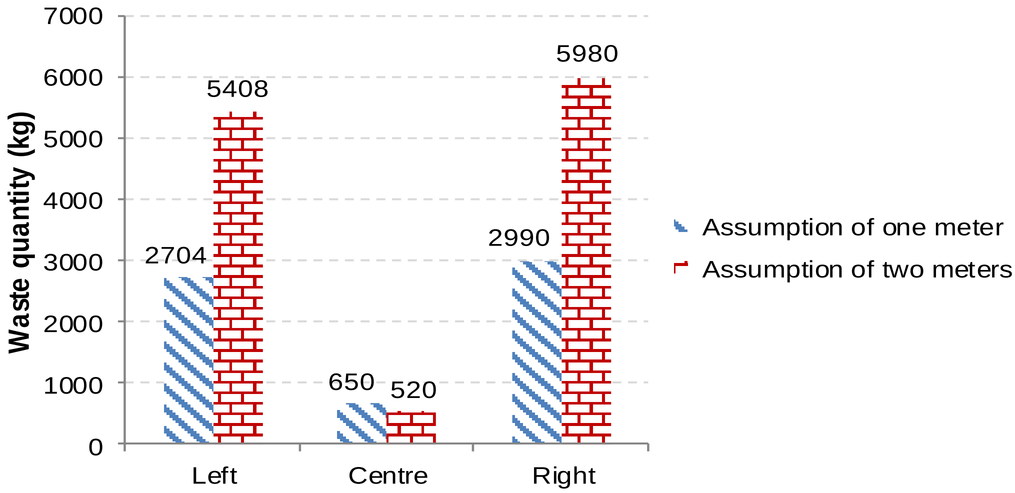

Figure 5-4 The estimated waste quantity for WL, WR, and WCE in Souq Alarab Street for both assumptions

5-2-3 Summary of Findings of Waste in Mina's Streets

The quantity of waste in a street in Mina with a large crowd and many facilities (food shops, mosque, etc.) on it (such as Alkaif Street) is expected to vary between 1603 kg and 2923 kg (for an 800 m length) at any given time, whereas the quantity of waste in a very busy street without facilities but just toilets and camp entrances (such as Souq Alarab Street) is estimated to be between 6344 kg and 11908 kg (for a 1300 m length) at any given time.

However, these quantities of waste are not distributed equally over the street but rather waste accumulated at the edges. This means that a huge quantity of waste was not disposed of in the street bins or in the compactor boxes. A main possible reason for that is the huge crowd, which meant there was limited access to the bins (**Figure 5-5**). It seems that when pilgrims throw their waste on the street, it was kicked by the crowd to the side of the street. Thus, as **Figures 5-3** and **Figure 5-4** show, waste accumulates at the edges more than in the centre of the street. However, the other sources of waste in

Mina's streets have been discussed in **Section 1-7-1,** which indicated that camps whose waste was thrown into the streets were one of the main reasons for waste accumulating in the streets. Although all these quantities of waste were collected, the waste accumulation process was much faster than waste removal process.

Figure 5-5 Limited access to Mina's street waste bins caused by the huge crowds (Souq Alarab Street)

5-3 Waste Composition for the Mina Camps

The goal of this section is to obtain the waste composition for the Mina camps according to the sampling plan (the first objective **OBJ1**, **Section 3-2**). The approach tries to capture the high level of variability anticipated between camps (because of the different socioeconomic and management conditions and opinions). Thus, there is often a difference between two camps from the same country. The approach included sampling and sorting for different waste materials.

5-3-1 The Sampling Plan Implementation

Forty different camps from different Tawafa companies were chosen to sort out waste samples from their marked compactor boxes according to the sampling plan (**Section 4-5-1**). However, there were five camps that did not use their compactor boxes because there was no waste inside the five compactor boxes (**Figure 1-17 and Section 1-7**). In addition, three compactor boxes were missing, that is, they were missing from the Municipality's list. This means that out of 40 compactor boxes, 8 boxes (13.5%) were excluded from this research, which means that this research was conducted in 32 out of the 40 chosen camps.

After the end of the Hajj (20/11/2010), Makkah Municipality moved all the compactor boxes to Makkah landfill and placed them in the waiting area (**Figure 5-6**). Their plan was to empty a specific number of boxes every day, wash them, and finally store them in a storage area. They were emptying the boxes in the middle of the landfill cell, which caused the waste to be mixed with other waste in that cell. Thus, the samples were collected directly from the boxes in the waiting area. As shown in **Figure 5-6,** access into the boxes was limited, and tipping out the box outside the cell, as had been planned, was not allowed. Consequently, the samples were taken from the entrance of the box or from the back door or from both when possible.

Although the number of collected waste bags ranged from 5 to 15, the samples' weights varied between 16.7 kg to 83.05 kg with an average of 41.4 kg (**Table A4, Appendix A**). This variation was caused by the heterogeneous waste contents in the waste bags. For instance, for some loads, the bags weighed about only 1 kg, and on-site-observation indicated that these bags were filled with plastic films (disposable plastic table sheets) or by other light plastic components (plastic cups and plates). Although it had been planned that the samples would be in the range of 91 to 136 kg, the time and place limitations led the researcher to collect the necessary number of bags (5-15 bags) without any consideration of their weight. The samples were extracted from the compactor boxes one by one, and each one was sorted out into the categories mentioned in **Section 4-5-2**.

Figure 5-6 Some of the Mina compactor boxes in the waiting area in Makkah landfill, where it can be seen that the access to these boxes was very limited

5-3-2 The Weight of Camps' Compactor Boxes

The total given weight of each compactor box, which was recorded by Makkah Municipality, varied between 1 t and 9 t with an average of 4 t (**Table A4, Appendix A**) (Cleaning Department, 2010). These numbers were rounded up to the nearest bigger integer, which might have led to the weight of the box being increased by about 0.9 t. Thus, if the weight of the compactor box was Z.x (x= 1 - 9) it was rounded up to Z+1. As a result, two values for the compactor box weight were used. The first one (minimum compactor box weight- MCW) was calculated by subtracting 0.9 t from the given weight whereas the second (maximum compactor box weight-XCW) was the same as the given weight.

Table A5 (**Appendix A**) shows, as a percentage, the calculated composition of the 32 camps grouped by different Tawafa companies while **Tables A6** and **A7** (**Appendix A**) show the total weight generated for each waste component per person ($g.p^{-1}$) in 20 camps for the minimum and maximum weight of the compactor boxes. Information regarding the number of pilgrims was not available for the remaining 12 camps because these camp managers did not keep a record of the number of pilgrims in their camps. These tables were done in detail for the ten waste groups, but the rest of the calculations were done for the major seven waste categories (**Section 4-5-2**).

5-3-3 Composition of the Compactor Boxes

Tables 5-5 shows the mean, upper, and lower levels of confidence at 95%, along with the median, standard deviation, standard error, and minimum and maximum values of the seven categories of waste components (all of these values as weight percentage and sorted as received). The main components according to the mean and level of confidence intervals in **Table 5-5** (as explained in **Section 4-5-3**) were in the following order: organic waste (29.3 ± 4.1%), all plastic (28± 3.5%), paper and cardboard (24.7± 4.5%), and all metals (11.2 ± 2.6%) at 95% level of confidence (**Figure 5-7**). These four groups represented (on average) 93.2% of the solid waste disposed of in the compactor boxes of the Mina camps, as shown in **Figure 5-8**, where waste composition for the 32 Mina camps was presented. As the 32 camps can be considered as a representative samples of all the Mina camps (**Section 4-5-1**), the waste composition is generalized for all the Mina camps.

Table 5-5 Descriptive statistics for the waste composition in the 32 camps (wt. % as received)

Waste component (wt. % as received)	Mean	Conf. -95%	Conf. +95%	Median	Std. Dev.	Std. Error	Min. value	Max. value
Organic waste	29.3	25.2	33.4	28.6	11.4	2.	8	57.1
All plastic	27.9	24.5	31.5	29	9.6	1.7	3.6	43.6
Paper and cardboard	24.7	20.2	29.3	20	12.5	2.2	6.7	54.4
All metals	11.2	8.6	13.8	10.8	7.2	1.3	0	26.5
Textile	4.1	1.8	6.4	0	6.5	1.1	0	20.3
Glass	2	0.2	3.9	0	5.1	0.9	0	20.3
Cork	0.7	-0.1	1.5	0	2.2	0.4	0	7.9

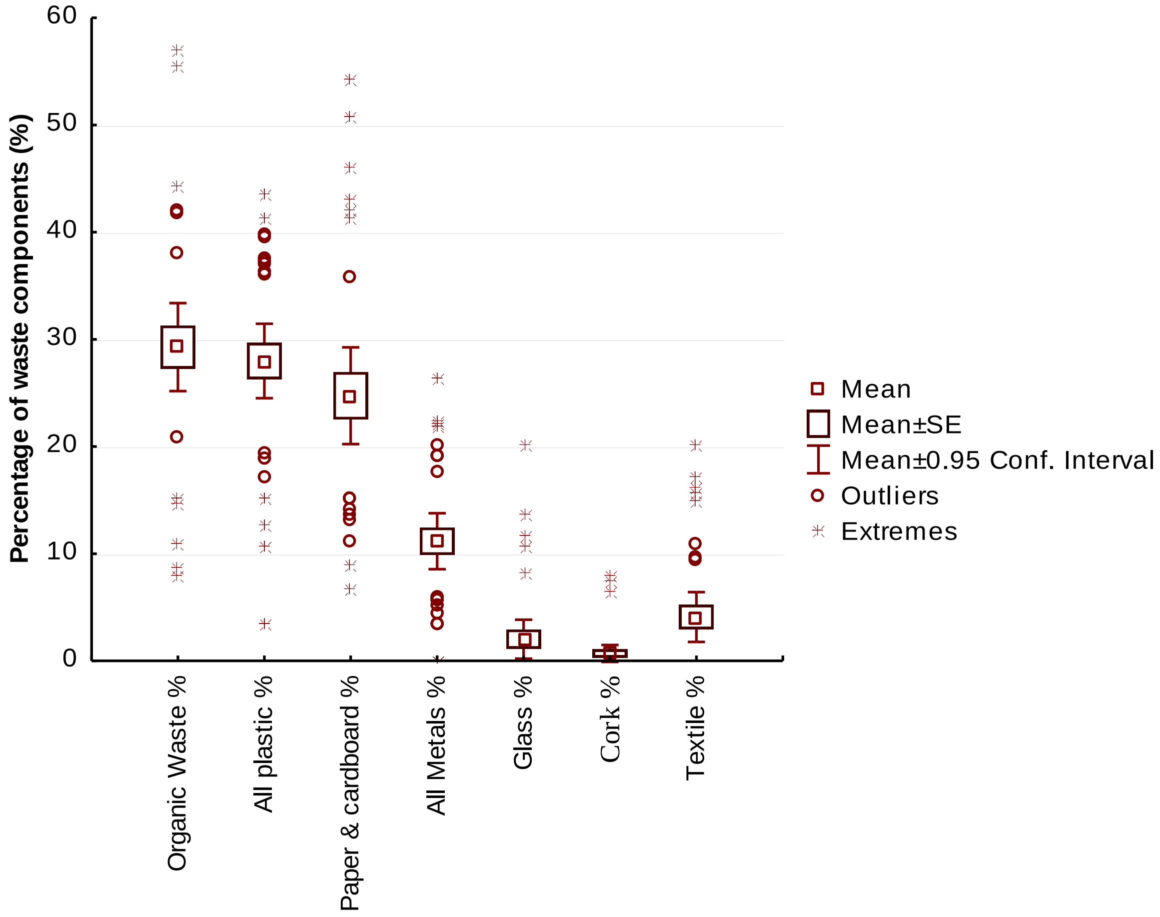

Figure 5-7 Box plots (Mean, ± SE and ±level of confidence intervals): waste components (wt. % as received) in the 32 camps, where organic waste, all plastic, and paper and cardboard appeared to be the main three components in the Mina camps. SE=standard error, conf. interval = confident interval, and Outliers and Extremes = values that are far from the middle of the distribution (STATISTICA, 2011)

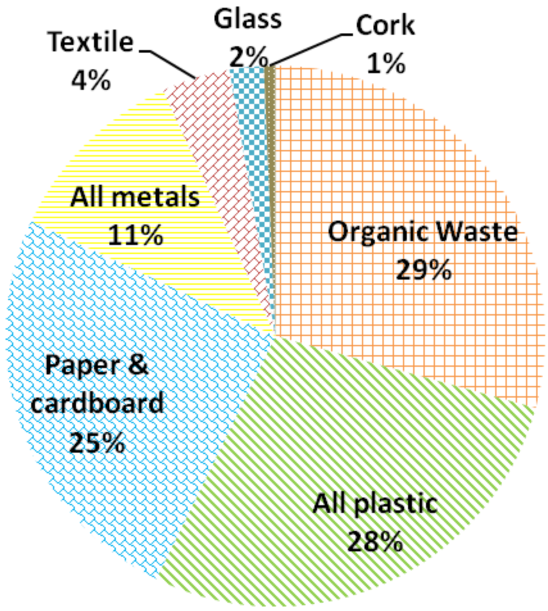

Figure 5-8 Waste composition for the representative chosen sample (32 camps) from the Mina camps, which is going to be generalized for all Mina camps

Table 5-6 Basic statistics for the waste composition in the 20 camps for MCW and XCW ($g.p^{-1}$)

Waste component ($g.p^{-1}$)	**Mean**	**Conf. -95%**	**Conf. 95%**	**Median**	**Std. Dev.**	**Std. Error**	**Min. value**	**Max. value**
Organic waste (MCW)	292	197	387	265	203	45	11	650
Organic waste (XCW)	388	289	488	359	213	48	95	746
All plastic (MCW)	276	172	380	258	222	50	1	730
All plastic (XCW)	354	239	470	351	247	55	14	837
Paper and cardboard (MCW)	213	126	299	152	185	41	7	538
Paper and cardboard (XCW)	275	179	371	205	204	46	53	624
All metals (MCW)	106	38	174	72	146	33	0	538
All metals (XCW)	139	64	214	97	161	36	0	598
Textile (MCW)	65	10	120	1	117	26	0	434
Textile (XCW)	86	21	152	9	140	31	0	482
Glass (MCW)	34	-7	74	0	87	19	0	358
Glass (XCW)	47	-4	97	0	108	24	0	436
Cork (MCW)	9	-5	23	0	30	7	0	125
Cork (XCW)	13	-5	31	0	37	8	0	152

Similarly, **Table 5-6** shows the basic statistics of the waste components ($g.p^{-1}$) for the compactor boxes from 20 camps based on MCW and XCW (as explained in **Section 4-**

5-3). It shows again that organic waste (292 ± 95 **and** 388 ± 100 g.p^{-1}), all plastic (276 ± 104 **and** 354 ± 115 g.p^{-1}), and paper and cardboard (213 ± 87 **and** 275 ± 96 g.p^{-1}) were the largest three components at 95% level of confidence. **Figure 5-9** shows, for the MCW and XCW, the mean ± standard error (SE) and ± level of confidence at 95% (g.p^{-1}).

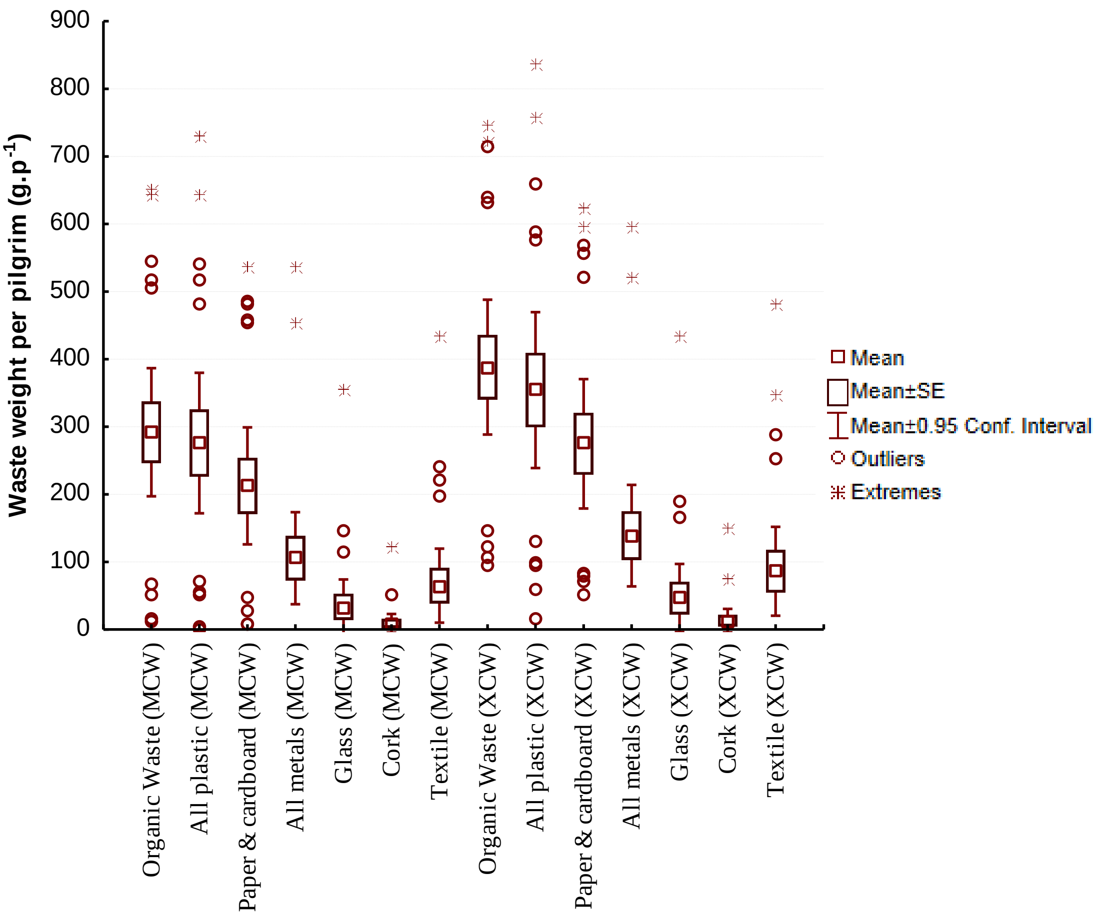

Figure 5-9 Box plots (Mean, ± SE and ±level of confidence intervals): waste components for the MCW and XCW for the 20 camps (g.p^{-1}), where organic waste, all plastic, and paper and cardboard appeared to be the main three components in the Mina camps

5-3-4 Average Weight of Waste Components in the Mina Camps

To estimate the quantity of each waste component from the Mina camps, the total weight of waste disposed of in the camps' compactor boxes needed to be known. However, although the exact quantity is unknown, it can be estimated. There were 723 compactor boxes allocated for all Mina camps out of the about 1000 boxes operating in Mina (**Section 1-7**).

The total collected waste from all compactor boxes was 2752 t (Cleaning Department, 2010). As a percentage, 73.7% of Mina compactor boxes were placed in Mina camps, which, assuming each camp had a compactor box with the same weight proportion, suggests the waste quantity of Mina camps can be estimated to be 2028 t (generated in five days). This quantity represents the quantity disposed of in compactor boxes not the generated quantity in camps. Based on this quantity, the weights of different waste components were calculated as shown in **Table 5-7**. However, if these percentages were generalized for all quantity of generated waste in Mina (17052 t), the expected quantity of the main waste components would be indicated, as shown in **Table 5-7**.

Table 5-7 The calculated weight of each waste component in Mina camps' compactor boxes and for overall Mina, where the percentages were taken from the results of the representative sample (32 camps)

Waste component	**Mean (wt. % as received)**	**Estimated weight of waste components in camps compactor boxes (t)**	**Estimated weight of waste components for overall Mina (t)**
Organic waste	29.3	593.8	4992.8
All plastic	27.9	567.4	4771.1
Paper and cardboard	24.7	501.7	4218.7
All metals	11.2	226.5	1904.7
Textile	4.1	83.1	699.1
Glass	2	41.2	346.2
Cork	0.7	14.0	117.7

5-3-5 Camps Waste Composition for Different Tawafa Companies

The quantities of waste disposed of per camp were not distributed equally between different Tawafa companies. **Figure 5-10** shows that South East Asia pilgrims disposed of the highest rate of waste per pilgrim whereas South Asia pilgrims disposed of the lowest rate. Possible reasons for this huge difference between the South East Asia Tawafa company and the other companies are because they used their compactor boxes more than did others or that they generated more waste than did others. Thus, this difference should be shown for each of the major waste components.

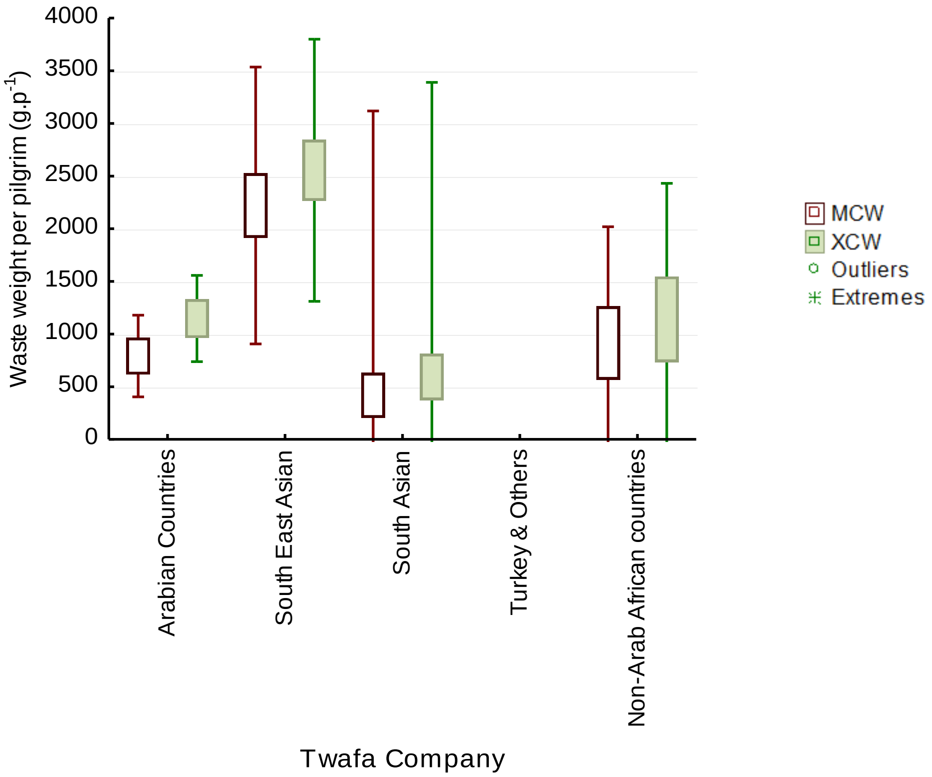

Figure 5-10 Box plots (Mean, ± SE and ±level of confidence intervals): quantities of waste disposed of per pilgrim (g.p^{-1}) grouped by Tawafa companies, where it can be seen that South East Asian pilgrims generated much more waste than did others

Organic waste

Although the average for organic waste disposed of in the 32 camps was (29.28 ± 4.1%), some camps (Saudi Arabia Pilgrims) disposed of 8% of organic waste in the compactor box (**Table 5-8**). **Figure 5-11** shows the mean of organic waste disposed of in the 32 compactor boxes (grouped by Tawafa companies), which are distributed around 30% except for the group of Saudi Arabian pilgrims (13.1%). A T-test shows that the p-values were not significant ($p > \alpha = 0.05$) in all groups except for the group of Saudi Arabian pilgrims where p values were significant ($p < \alpha = 0.05$) in contrast to all other groups as shown in **Table 5-9**. This means that there is no difference in the means of the generated organic waste between all Tawafa companies except the company of Saudi Arabian pilgrims. However, it is believed that not all organic waste generated was disposed of in the compactor boxes (**Figure 5-12).** In addition, many camps managers did not provide any kind of food to their pilgrims (pilgrims bought their food from food shops outside their camps). Usually, in such camps, the percentage of the organic waste was low (as noted).

Table 5-8 Basic statistics of the organic waste grouped by Tawafa companies (wt. % as received)

Tawafa Company	**N**	**Mean**	**Conf. -95%**	**Conf. +95%**	**Median**	**Min.**	**Max.**	**Std. Dev.**	**Std Error**
Arabian countries	12	30.4	25.0	35.8	28.4	14.7	44.4	8.6	2.5
South East Asian	3	27.8	18.6	37.0	27.7	24.1	31.5	3.7	2.1
South Asian	3	32.3	30.2	34.3	32.7	31.3	32.8	0.8	0.5
Turkey and others	4	37.9	16.2	59.7	34.8	26.5	55.6	13.7	6.8
Non-Arab African countries	4	35.7	12.1	59.2	31.3	23.1	57.1	14.8	7.4
Iran	1	31.9	--	--	31.9	31.9	31.9	--	--
Saudi Arabia pilgrims	5	13.1	5.7	20.6	11.1	8.0	22.7	6.0	2.7

Table 5-9 P-values for organic waste (wt. % as received) from T-test (independent samples grouped by Tawafa Company at 95% level of confidence), p-value is in red when it is statistical significant

	Arabian Countries	South East Asian	South Asian	Turkey and Others	Non-Arab African countries	Saudi Arabia Pilgrims
Arabian countries						
South East Asian	0.62					
South Asian	0.72	0.11				
Turkey and others	0.21	0.28	0.52			
Non-Arab African countries	0.39	0.42	0.71	0.83		
Saudi Arabia pilgrims	0.001	0.01	0.002	0.0078	0.016	

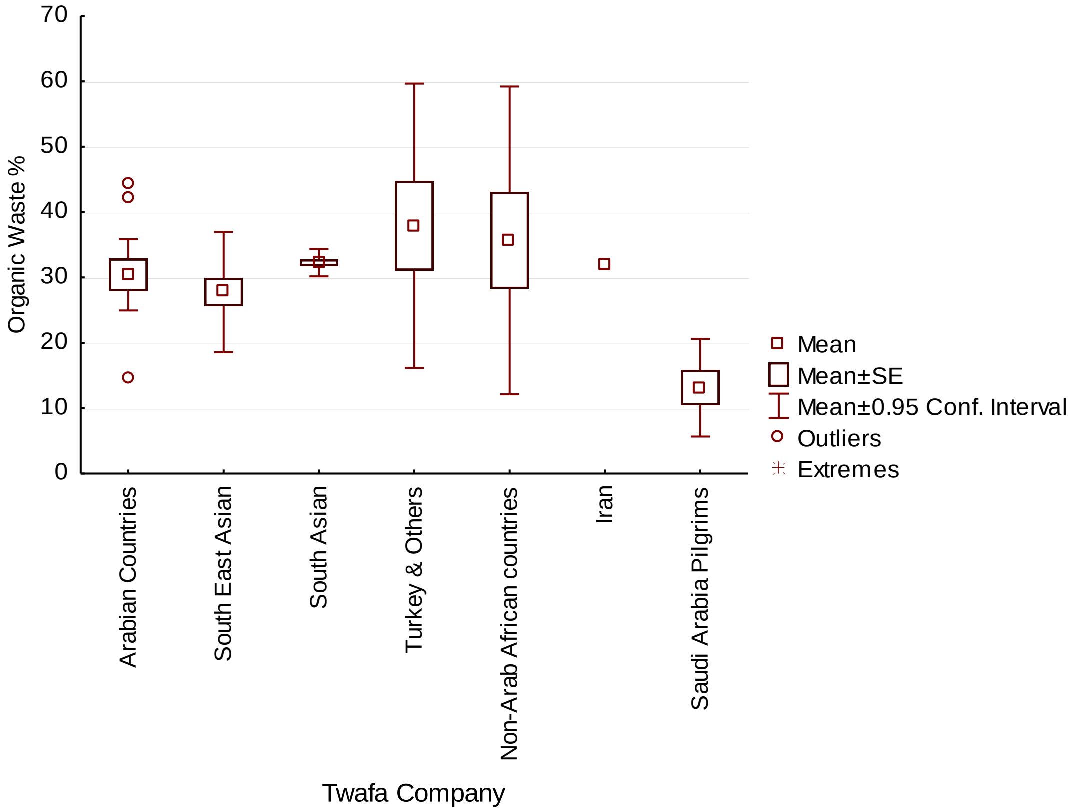

Figure 5-11 Box plot (Mean, ± SE and ±level of confidence intervals): the percentages of organic waste grouped by Tawafa Company, where the only statistically significant difference is between Saudi Arabia and other groups

Although the percentages of organic waste in most of the Tawafa companies were convergent, the mean weights per pilgrim ($g.p^{-1}$) of organic waste disposed of were not similar. **Figure 5-13** illustrates that South East Asian pilgrims' disposed of the greatest quantity of organic waste per pilgrim. A T-test demonstrated that the p-values of South

East Asian pilgrims Tawafa Company were statistically significant, which means there is a difference between the mean of this company and those of other companies (**Table 5-10**). One of the main causes of this is that the pilgrims in this company consumed a large amount of food (4 – 6 meals daily provided to them(Mashat, 2011)), which did not occur in any other Tawafa companies. This seems to be the main reason for the high quantity of waste disposed of per pilgrim in this company.

Figure 5-12 One of the Egyptian camps' foods residuals disposed of in the street bin. There were two bins filled with cooked rice beside the camp gate, which showed how food residuals were just thrown away as waste

Table 5-10 P-values for organic waste ($g.p^{-1}$ for XCW) from T-test (independent samples by group at 95% level of confidence)

	South East Asian	Arabian countries	South Asian	Non-Arab African countries
South East Asian				
Arabian countries	0.01			
South Asian	0.005	0.27		
Non-Arab African countries	0.03	0.96	0.29	

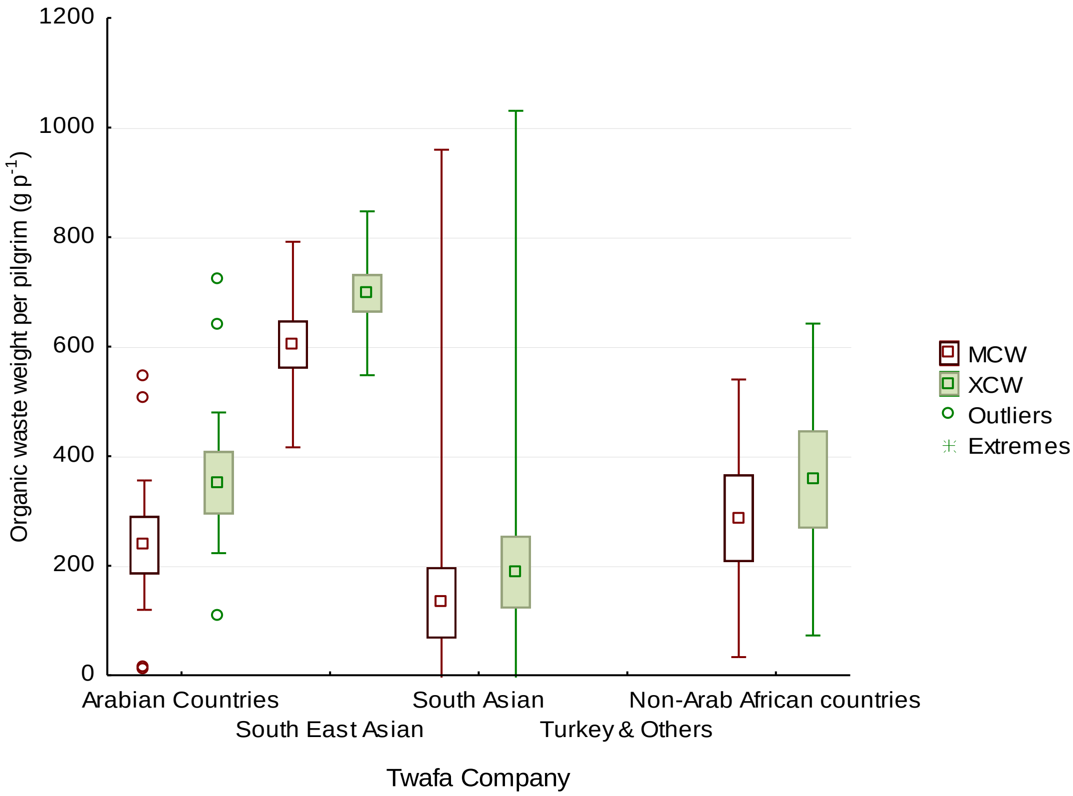

Figure 5-13 Box plots (Mean, ± SE and ±level of confidence intervals): the quantities of organic waste (g.p^{-1}) grouped by Tawafa Company, where South East pilgrims generated the majority of the organic waste

<u>Plastic waste</u>

The mean of plastic waste (plastic film + other plastic) disposed of in each Tawafa company varied from 23.2% to 36.1% (**Table 5-11**) with an average of 28%. The plastic waste was the only component in waste of the Mina camps, where it represented about a quarter to one-third of the waste disposed of in the compactor boxes in all the Tawafa companies without exception (**Figure 5-14**). In addition, T-test results supported this as shown in **Table 5-12** where all p-values were non-significant (there were no differences in the means of plastic percentages of all Tawafa companies).

Table 5-11 Basic statistics of plastic grouped by Tawafa companies (wt. % as received)

Tawafa Company	N	Mean	Conf. -95%	Conf. +95%	Median	Min.	Max.	Std. Dev.	Std Error
Arabian countries	12	23.2	16.4	29.9	25.7	3.6	37.4	10.6	3.1
South East Asian	3	27.8	9.5	46.1	31.1	19.4	33.0	7.4	4.3
South Asian	3	30.1	8.9	51.3	26.5	23.9	39.8	8.5	4.9
Turkey and others	4	27.5	10.9	44.1	28.6	15.1	37.7	10.4	5.2
Non-Arab African countries	4	32.8	18.2	47.5	32.2	23.3	43.6	9.2	4.6
Iran	1	36.1			36.1	36.1	36.1		
Saudi Arabian pilgrims	5	33.3	24.3	42.2	30.9	23.8	41.3	7.2	3.2

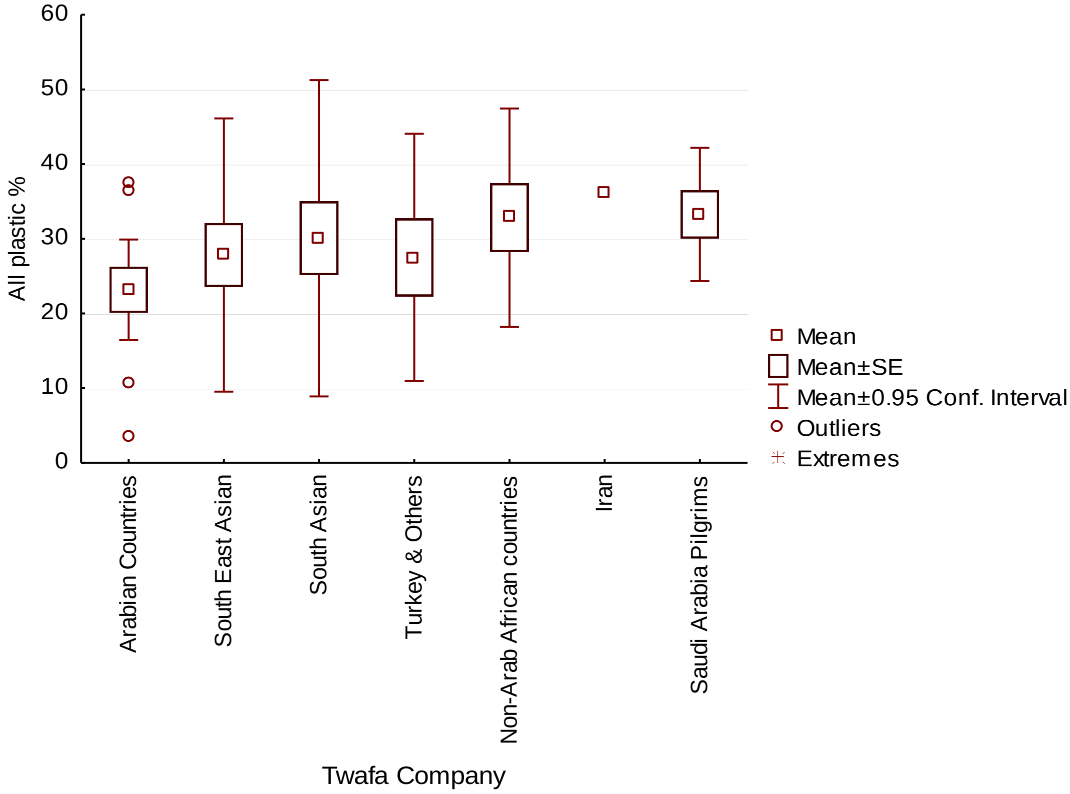

Figure 5-14 Box plots (Mean, ± SE and ±level of confidence intervals): the percentage of all plastic waste grouped by Tawafa Company, where it can be seen that there was no major difference between all companies

Table 5-12 P-values for all plastic % from T-test (independent samples by group at 95% level of confidence)

	Arabian Countries	South East Asian	South Asian	Turkey and others	Non-Arab African countries	Saudi Arabia pilgrims
Arabian countries						
South East Asian	0.49					
South Asian	0.32	0.75				
Turkey and others	0.49	0.97	0.74			
Non-Arab African countries	0.13	0.48	0.7	0.47		
Saudi Arabian pilgrims	0.072	0.35	0.59	0.36	0.94	

Although the percentages of plastic disposed of in all the Tawafa companies were similar, the quantities of plastic disposed of per pilgrim were dissimilar (**Figure 5-15**). The dissimilarity occurred again between the South East Asia Tawafa Company and the rest as the T-test results confirmed that the p-values derived from the T-test were statistically significant (**Table 5-13**).

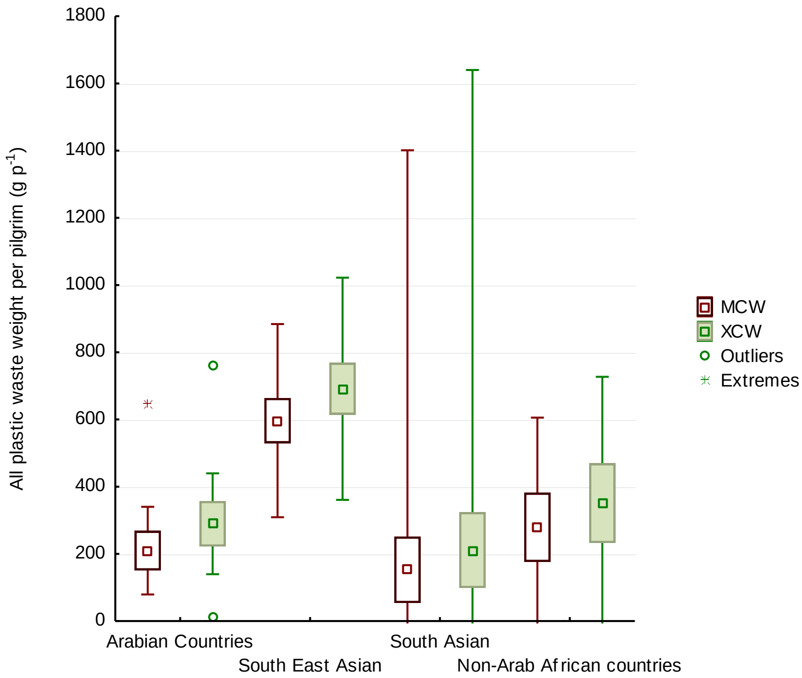

Figure 5-15 Box plots (Mean, ± SE and ±level of confidence intervals): the quantities of plastic waste ($g.p^{-1}$) grouped by Tawafa Company

Table 5-13 P-values from T-Test for independent samples by group at 95% level of confidence, for all plastic (g.p^{-1} for XCW)

	South East Asian	Arabian countries	South Asian	Non-Arab African countries
South East Asian				
Arabian countries	0.012			
South Asian	0.034	0.65		
Non-Arab African countries	0.08	0.65	0.5	

Paper and cardboard

The average quantity of paper and cardboard disposed of in the studied camps, which mostly came from packaging and paper juice cartons, was 24.7%, but it varied from 6.7% to 54.4%. **Figure 5-16** shows the mean percentages of paper and cardboard disposed of in each Tawafa company, where the figure illustrated that the means of all companies of disposed of paper and cardboard were around 20% except the company of Saudi pilgrims (44.9%). The p-values derived from the T-test supported the idea that there were no differences in the means of all the Tawafa companies except for the company of Saudi Arabia pilgrims, where the p-values were significant (**Table 5-14**).

This result seems to confirm the suggested view about the Saudi Arabia pilgrims' camps, that is, that they used the compactor boxes to dispose of just the dry waste (Mashat, 2011). As a result, in the Saudi pilgrims' camps, the percentage of organic waste was very low (in comparison with the percentages for other Tawafa companies) while the percentage of dry waste (plastic + paper and cardboard) was high.

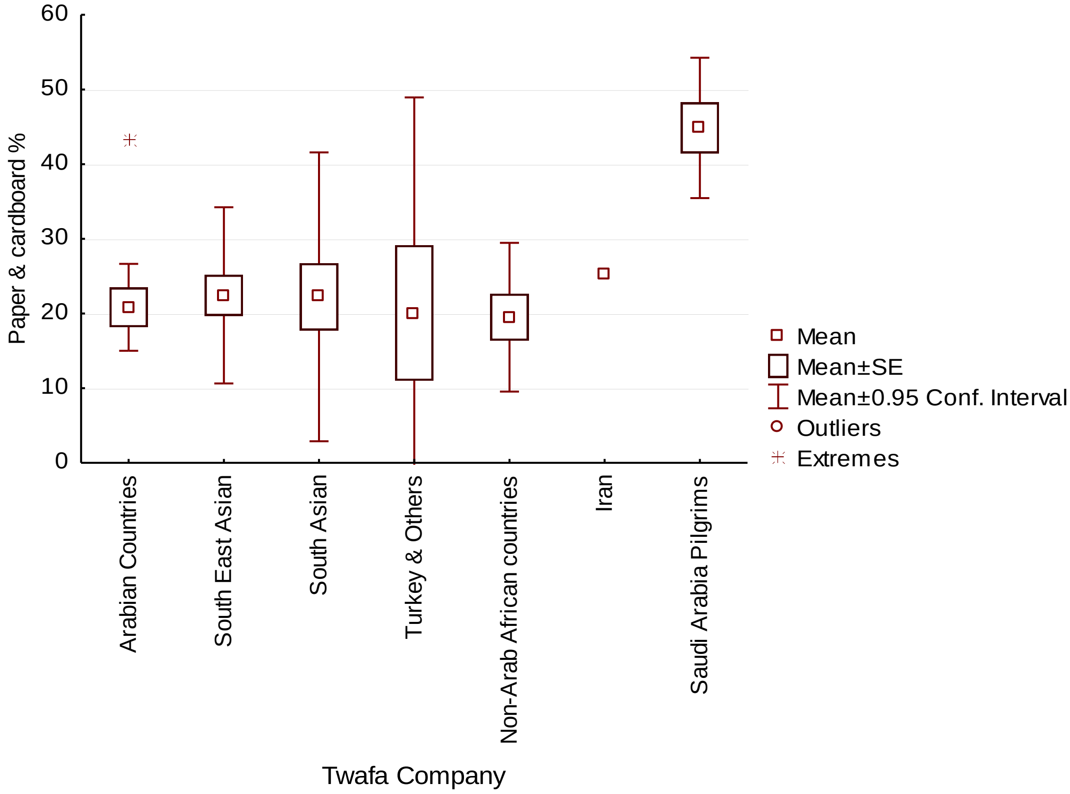

Figure 5-16 Box plots (Mean, ± SE and ±level of confidence intervals): the percentages of paper and cardboard grouped by Tawafa Company, where the only statistically significant difference is between Saudi Arabia and other groups

Table 5-14 P-values for paper and cardboard % from T-test (independent samples by group at a 95% level of confidence)

	Arabian countries	South East Asian	South Asian	Turkey and others	Non-Arab African countries	Saudi Arabian pilgrims
Arabian countries						
South East Asian	0.78					
South Asian	0.81	0.97				
Turkey and others	0.91	0.84	0.86			
Non-Arab African countries	0.79	0.53	0.63	0.95		
Saudi Arabian pilgrims	0.0001	0.004	0.0067	0.026	0.001	

On the other hand, the mean quantities of the paper and cardboard disposed of per pilgrim were convergent in three Tawafa companies (Arabian countries, South Asia and non-Arabic African countries) while the South East Asia Tawafa Company was the highest (**Figure 5-17**). The T-test result showed that the p-values were significant for the South East Asia Tawafa Company (**Table 5-15**).

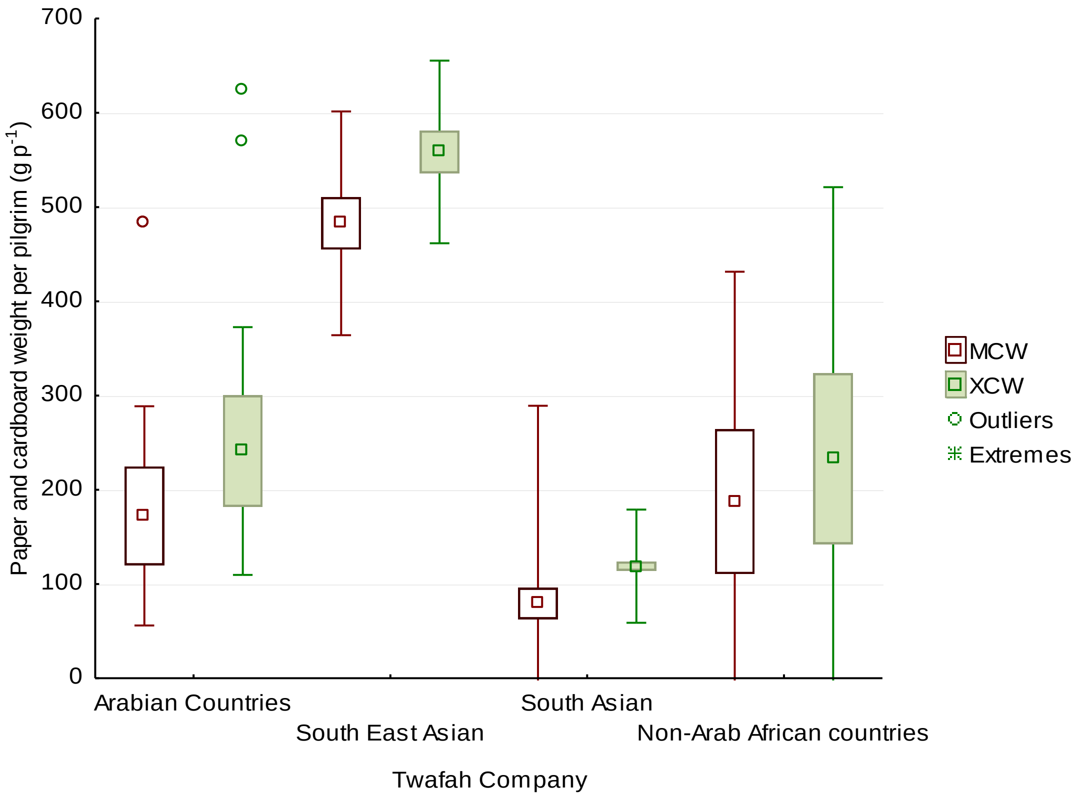

Figure 5-17 Box plots (Mean, ± SE and ±level of confidence intervals): the quantities of paper and cardboard (g.p^{-1}) grouped by Tawafa Company

Table 5-15 P-values from T-Test for independent samples by group at a 95% level of confidence, for paper and cardboard (g.p^{-1} for XCW)

	South East Asian	Arabian countries	South Asian	Non-Arab African countries
South East Asian				
Arabian countries	0.02			
South Asian	0.0006	0.41		
Non-Arab African countries	0.03	0.94	0.45	

5-3-6 Summary of composition of camp waste

Overall, about 82% of the waste of the Mina camps consisted of organic waste (29%), plastic (28%), and paper and cardboard (25%). All the Tawafa companies generated similar percentages of organic waste and paper and cardboard except for the Saudi pilgrims. However, all the pilgrims generated a similar percentage of plastic (about one-third of their waste). On the other hand, in terms of waste generation per pilgrim, the South East Asian pilgrims produced the greatest quantity of waste per pilgrim from among the four investigated Tawafa companies, whereas the South Asian pilgrims generated the lowest. It is believed that the pilgrims in the South East Asian Tawafa company produced more waste than the others because they consumed more food (the input to the system was high, so the output waste was higher than the average).

5-4 ISWM benchmark indicators for SWM System in Mina

Although the Wasteaware ISWM benchmark tool (**Section 2-4**) was developed to assess SWM systems in cities, it was applied to Mina on the basis that for the five Hajj days, the population levels and waste generation are of city-like proportions (**Section 4-6)**. Using the methodology explained (**Section 4-6**) and data collected about the SWM system in Mina, this framework was implemented. This was done through following the guidelines in the user manual to complete the nine tables of the different indicator groups of this framework (Wilson et al., 2013b). **Tables 5-16** to **5-24** show the nine tables filled with Mina SWM data whereas **Table 5-25** and **Figure 5-18** show a summary of the results.

Completing these tables required a degree of subjective/professional judgment, and it was evident on a number of occasions that alternative assumptions could have been made. Comments and references in the tables cover the reasons for the choices made. To illustrate where an assumption had a significant impact, consider indicator 1.2: waste captured by the SWM system. Here, only waste captured in the designated compactors during the five Hajj days is considered to be "captured"; waste manually cleared from the streets in the post Hajj clean-up is excluded. Using this definition indicates the SWM system captured only 36% of the total. If this had been the result for an established city, it would have been considered a major failure and indicative of huge quantities of dumped waste throughout the city and its environs. For Mina, it simply means there is a massive clean-up operation once the pilgrims have left the "site".

One could have defined the Mina collection system as including this clean-up operation as an integral element in the collection system and so achieved a score of "100%". However, the intention and aim of the compaction systems is to capture all the waste and, in this context, the 36% score is a fair reflection of how well it performed. However, the consequential impact of failure in terms of direct environmental damage is rather minimal compared to an established city, which would have no mechanisms or any opportunity to "clean up" later

This example highlights that whilst the Wasteaware framework and indicators are relevant for assessing waste management in cases such as Mina, and can highlight problem areas, the fact that it is a mega event/temporary city rather than an established community suggests that the direct comparison of performance results may not be justified.

Table 5-16 Wasteaware ISWM benchmark indicators, background information about Mina

No.	Category	Indicator	Value	Justification
B1	Income level	GNI per capita	Not applicable	**Section 4-6**
B2	Population	Total population of the city	3,690,000	2.79 million legal pilgrims + 0.9 million illegal pilgrims (**Section 1-2**)
B3	Waste generation	Total municipal solid waste generation (t per year)	17,052	This quantity was generated in five days only (**Section 1-7**), but it represented the weight of the waste disposed of in the landfill. However, the waste from the slaughter houses was not included in this figure as it is not part of SWM in Mina, there being a special landfill for it. In 2007, Mina slaughter houses produced 4900 t of waste (about 10% of this quantity was recycled) and 1113 t of blood (Aziz et al., 2007).
W1	Waste per capita	MSW per capita (kg.year^{-1})	4.6	Five days only (**Section 1-7**)
		MSW per capita (kg.d^{-1})	0.92	
W2	Waste composition	Summary composition of MSW as generated. Data points used for 3 key fractions – all as % wt. of total waste generated	-	-
W2.1	Organic	Organics (food and green wastes) %	30	Camps waste composition (**Section 5-3-3**)
W2.2	Paper	Paper %	25	
W2.3	Plastics	Plastics %	28	
W2.4	Metals	Metals %	11	
W2.5	Solid waste density	Solid waste density kg.m^{-3}	Unknown	**Section 4-6**
W2.6	Moisture content	Moisture content %	Unknown	

Table 5-17 Wasteaware ISWM benchmark indicators, indicators 1 and 1C filled with Mina data

No.	Short name	Score	Justification
1.1	Waste collection coverage (%)	100	All waste must been removed after the season
	Quantitative assessment		**Table 4-10**
1.2	Waste captured by the solid waste management system (%)	36	Total weight of the waste collected in the compactor boxes = 2824 t (capacity = 8072 t) and in the underground storage boxes = 3368 t (capacity = 6950 t). The total collected waste in the collection system = 6192 t. This quantity represents 36.3% of the total collected waste in Mina, which was 17052 t. In addition, just 41.2% of the system capacity was used but if it were used fully, it would be enough for 88% of the generated waste.
	Quantitative assessment		**Table 4-10**
1C	**Quality of waste collection and street cleaning service**		

1C.1	Appearance of waste collection points	5	Figures 1-17, 1-18, 1-19,1-20 and 1-21
1C.2	Effectiveness of street cleaning	10	Figures 1-16, 1-18, 1-19, 1-20, 5-1 and 5-2
1C.3	Effectiveness of collection in low income districts	5	Some camps disposed of their waste on streets (**Section 1-7-2**)
1C.4	Efficiency and effectiveness of waste transport	15	All waste transported to the landfill directly in boxes or closed vehicles, but some of the waste collected after the season is transported by big open trucks
1C.5	Appropriateness of service planning and monitoring	15	A private sector with appropriate contracts
1C.6	Health and safety of collection workers	5	Workers were just given yellow overalls and hats
	Total score	**55**	Summation of the scores above
	Normalised %	**46**	Conversion of this total out of 120 to a %
1C	**Qualitative assessment**		**Table 4-10**

Table 5-18 Wasteaware ISWM benchmark indicators, indicators 2 and 2E filled with Mina data

No.	**Short name**	**Score**	**Justification**
2	Controlled treatment or disposal (%)	20	Uncontrolled dumping in the landfill. Without any treatment or separation of organic or hazardous waste
	Quantitative assessment		**Table 4-10**
2E	**Quality of environmental protection of waste treatment and disposal**		
2E.1	Degree of control over waste reception and general site management	10	Available criteria were vehicular access to the site, site security and waste reception
2E.2	Degree of control over waste treatment and disposal	10	Waste is daily compacted and covered in the landfill
2E.3	Degree of monitoring and verification of environmental controls	0	There is just a record at the reception of the weight of the waste in each incoming vehicle
2E.4	Efficiency of energy generation and use (used for energy recovery facilities only)	0	There is no energy recovery
2E.5	Degree of technical competence in the planning, management and operation of treatment and disposal	10	Private sector with proper tools and staff trained to low level in the landfill to run weighing system
2E.6	Occupational health and safety	10	Staff have boots, gloves, and hats
	Total score	**40**	Summation of the scores above
	Normalised %	**33**	Conversion of this total out of 120 to a %
2E	**Qualitative assessment**		**Table 4-10**

Table 5-19 Wasteaware ISWM benchmark indicators, indicators 3 and 3R completed using Mina data

No.	Short name	Score	Justification
3	Recycling rate (%)	0	It is expected that all quantities of generated waste in Mina are transferred to the landfill. However, it seems, based on the on-site observations, that a limited number of waste pickers were seen in Mina after the end of the event (while the cleaning workers were collecting the waste). However, these waste pickers and some of the cleaning workers were not looking for recyclable waste but they were searching for valuables (as some of them said) that pilgrims had lost (such as money, mobiles and jewellery). In addition, waste pickers are not allowed to enter the landfill. Thus, it is assumed that there is no formal or informal recycling in Mina.
	Quantitative assessment		**Table 4-10**
3Q	**Quality of resource management - reduce, reuse, recycle**		
3R.1	Source separation of ‘dry recyclables’	0	
3R.2	Quality of recycled organic materials.	0	
3R.3	Focus on the top levels of the waste hierarchy	0	
3R.4	Integration of the community and/or informal recycling sector (IRS) with the formal solid waste management system	0	
3R.5	Environmental protection in recycling	0	
3R.6	Occupational health and safety	0	
	Total score	**0**	Summation of the scores above
	Normalised %	**0**	Conversion of this total out of 120 to a %
3Q	**Qualitative assessment**		**Table 4-10**

Table 5-20 Wasteaware ISWM benchmark indicators, indicator 4U filled with Mina data

No.	Short name	Score	Justification
4U	**User inclusivity**		
4U.1	Equity of service provision	20	All Mina camps and streets received the same solid waste services
4U.2	The right to be heard	0	Pilgrims were not included in the decision making
4U.3	Level of public involvement	0	Pilgrims were not included in the decision making
4U.4	Public feedback mechanisms	0	There was no public feedback
4U.5	Public education and awareness	15	Many educational campaigns by posters and press to encourage pilgrims dispose of their waste in the bins

4U.6	Effectiveness in achieving behaviour change	10	There was no educational campaigns in the last 10 years
	Total score	**45**	Summation of the scores above
	Normalized %	**38**	Conversion of this total out of 120 to a %
4U	**Qualitative assessment**		**Table 4-10**

Table 5-21 Wasteaware ISWM benchmark indicators, indicator 4P filled with Mina data

No.	Short name	Score	Justification
4P	**Provider inclusivity**		
4P.1	Legal framework	15	There are regulations to organise the participation of Tawafa companies through field service offices; for example, when managing the waste inside the Mina camps, it is the responsibility of the camp managers to use the compactor boxes to dispose of camp waste, and if they throw their waste into street, they will be fined SR10000 (**Section 1-7-2**)
4P.2	Representation of the private sector	0	There is no informal sector involved in SWM in Mina (Alsebaei, 2010)
4P.3	Role of the 'informal' and community sector	0	There is no informal sector involved in SWM in Mina (Alsebaei, 2010)
4P.4	The balance of public vs. private sector interests in delivering services	15	There is a cleaning contract (Alsebaei, 2010) and penalties are applied (**Section 1-7**),
4P.5	Bid processes	10	There is a clear contract (Alsebaei, 2010)
	Total score	**40**	Summation of the scores above
4P	**Qualitative assessment**		**Table 4-10**

Table 5-22 Wasteaware ISWM benchmark indicators, indicator 5F filled with Mina data

No.	Short name	Score	Justification
5F	**Financial Sustainability**		
5F.1	Cost accounting	15	The cost is known
5F.2	Coverage of the available budget	20	Government covers all the (Alsebaei, 2010)
5F.3	Local cost recovery – from households	0	None
5F.4	Affordability of user charges	n/a	N/A
5F.5	Coverage of disposal costs	0	No charge for solid waste disposal
5F.6	Access to capital for investment	20	The government provides all necessary funds
	Total score	**55**	Summation of the scores above
	Normalised score (%)	**55**	Conversion of this total out of 100 to a %
5F	**Qualitative assessment**		**Table 4-10**

Table 5-23 Wasteaware ISWM benchmark indicators, indicator 6N filled with Mina data

No.	Short name	Score	Justification of score
6N	**National SWM Framework**		
6N.1	Legislation and regulations	0	There are just general environmental legislations about waste collection (MOMRA, 2009) and design of landfill (MOMRA, 2003)
6N.2	Strategy/policy	5	There is national environmental plan but there is no great focus on SWM especially on Mina. For instance, in the ninth nation (development) plan, only five lines were written about SWM generally in Saudi Arabia and about how the landfills need to be studied more (MEP, 2010)
6N.3	Guidelines and implementation procedures	5	As mentioned previously, the focus is on waste collection and disposal at the landfill but nothing about recycling or resource recovery
6N.4	National institution responsible for implementing solid waste management policy	15	Makkah Municipality is responsible about SWM in Mina
6N.5	Regulatory control	5	MOMRA legislate regarding SWM collection and landfill but there is no enforcement to make municipalities apply these legislations especially regarding Mina
6N.6	Extended producer responsibility (EPR) or product stewardship (PS)	0	The Saudi government is the only body paying for SWM without making any profits
	Total score	**30**	Summation of the scores above
	Normalised score (%)	**25**	Conversion of this total out of 120 to a %
6N	**Qualitative assessment**		**Table 4-10**

Table 5-24 Wasteaware ISWM benchmark indicators, indicator 6L filled with Mina data

No.	Short name	Score	Justification of score
6 L	**Local institutional coherence**		
6L.1	Organisational structure	20	
6L.2	Institutional capacity	15	There are problems associated with staff qualifications and training, as could be observed as there were mostly seasonal staff that had been trained for three months or less.
6L.3	City-wide solid waste management strategy and plan	20	There is a plan (**Section 1-7**) and enough funds.
6L.4	Availability and quality of solid waste management data	5	The only information they have is about the weight of the disposed of waste.
6L.5	Management, control and supervision of service delivery	15	There were many supervisors from Makkah Municipality to monitor the contractor's cleaning workers. They were authorized to issue fines if any problem occurred because of the cleaning workers.
6L.6	Inter-municipal (or regional) co-operation	10	Based on the interviews with officials from the Mina authorities, it was found that there was no great cooperation between them and with Tawafa companies (Alsebaei, 2010)

	Total score	**85**	Summation of the scores above
	Normalised score (%)	**71**	Conversion of this total out of 120 to a %
6L	**Qualitative assessment**		**Table 4-10**

Table 5-25 Wasteaware ISWM benchmark indicators, summary of Mina SWM results

Background information on Mina							
City		**Mina**					
Country		Saudi Arabia					
Date since previous application of indicators:				2010			
B1	Country income category	World Bank income category		Gross National Income (GNI) per capita			
		Not applicable		Not applicable			
B2	Population of city	Total population of the city		3,690,000			
B3	Waste generation	Total municipal solid waste generation (metric tons per year)		17052			
No	**Category**	**Data/ Benchmark Indicator**		**Results**	**Code**		**Progress**
Key Waste-related data		***Data***			-	-	-
W1	Waste per capita	MSW per capita	$kg.year^{-1}$	4.6	-	-	
			$Kg.d^{-1}$	0.92	-	-	
W2	Waste composition:	Summary composition of MSW for 3 key fractions – all as % wt. of total waste generated		-	-	-	-
W2.1	Organic	Organics (food and green wastes) %		30	-	-	-
W2.2	Paper	Paper %		25	-	-	-
W2.3	Plastics	Plastics %		28	-	-	-
W2.4	Metals	Metals %		11	-	-	-
W2.5	Solid waste density	Solid waste density		Unknown	-	-	-
W2.6	Moisture content	Moisture content		Unknown	-	-	-
Physical Components		***Benchmark Indicator***		-	-	-	-
1	Public health – waste collection	1.1 Waste collection coverage		100			
		1.2 Waste captured by the system		36			
1C		Quality of waste collection service		46			
2	Environmental control – waste treatment, and disposal	Controlled treatment and disposal		20			
2E		Quality of environmental protection of waste treatment and disposal		33			
3	Resource Management	Recycling rate		0			

3R	– reduce, reuse, recycle	Quality of 3Rs – reduce, reuse, recycle	0			
Governance Factors		***Benchmark Indicator***	-			-
4U	Inclusivity	User inclusivity	38			
4P		Provider inclusivity	40			
5F	Financial sustainability	Financial sustainability	55			
6N	Sound institutions, proactive policies	Adequacy of national solid waste management framework	25			
6L		Local institutional coherence	71			

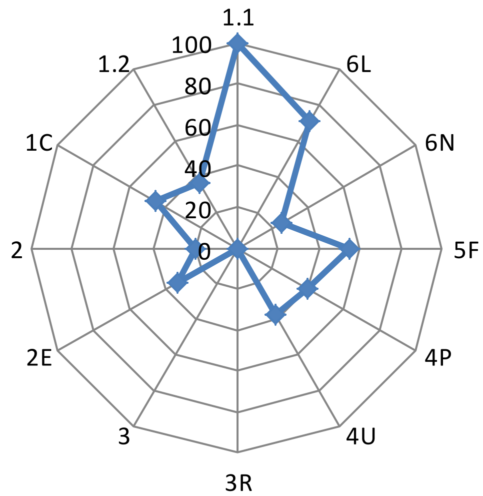

Figure 5-18 Radar diagram summarising the Wasteaware ISWM benchmark indicators for Mina for which the data are presented in **Table 5-25**, where it can be seen that waste collection in Mina had the highest percentage in this framework whereas recycling had the lowest score (0%)

5-4-1 Summary of Wasteaware ISWM Benchmark Indicators Assessment for SWM in Mina

The results for the Wasteaware ISWM benchmark indicators on Mina SWM (**Table 5-25 and Figure 5-18**) show that the SWM system in Mina is weak; thus, it requires many improvements. Overall, the main strength and priority of this system is in the percentage of waste collection coverage as well as the strength and coherence of Makkah Municipality's strategy to control waste in Mina; however, the waste disposal and recycling indicators had the lowest scores. In addition, in governance aspects indicators, the authority should have clear national legislation and strategy for SWM in Mina, and pilgrims should be involved in SWM planning. These four areas need to be improved, which should lead to better SWM in Mina. This seems to support the claim that Makkah Municipality is trying to make the waste in Mina less visible by putting all the effort only into waste collection but not making any effort to manage it properly (**Section 1-7**). In addition, it is believed that the problem is not in funding or manpower or even local institutions; instead, the problem is mainly in the lack of proper environmental planning and management.

5-5 Camp Managers' Questionnaire and Assessment of Compactor Boxes

As mentioned previously, in spite of the neglected forms, a total of 103 forms were fully completed, each one representing one camp manager. These 103 camps represented 4 Tawafa companies (**Figure 5-19**) and an unknown number of countries. This is because the 40 camps accommodated more than one country in the same camp (for countries that had only a small number of pilgrims).

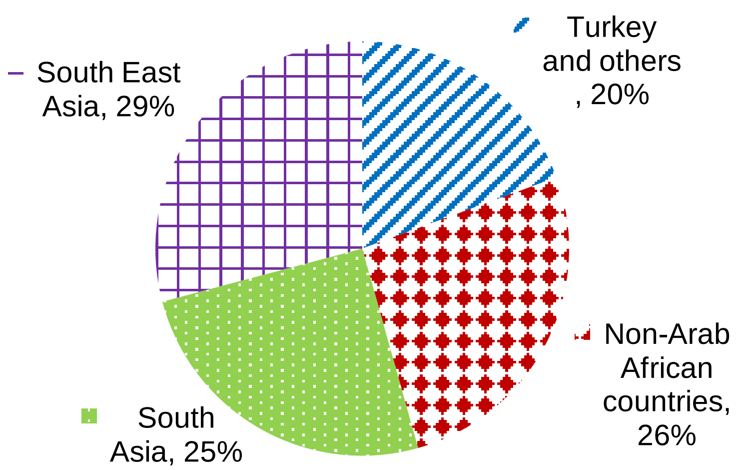

Figure 5-19 The percentage of managers' questionnaires filled in for each Tawafa Company

The responses to the questionnaire were varied, sometimes between Tawafa companies and sometimes between different countries within the Tawafa companies. However, these responses were based on just the camp managers' opinions; while there were no right answers, they sometimes gave unrealistic answers to cover their own negligence (as was observed). For instance, many camp managers said that all of the generated waste in their camps was disposed of in the camp compactor box whereas, based on on-site observation, it was found that some of them threw a portion of their waste (especially the food residuals) into the street beside the fire exit behind the camp.

Question One: ***Do you provide meals for the pilgrims in your camp?***

The objective of this question was to understand the catering services inside the Mina camps. As meals are the main cause of waste production in the Mina camps, it was necessary to identify whether those meals were provided to the pilgrims or if they had to buy their own food from outside the camp. **Figure 5-20** shows the percentage of the answers for this question, where it is illustrated that almost three quarters of the managers (81 out of 103) provided food services to their pilgrims even if only occasionally.

Question Two: W*hich meal do you provide?*

Complementary to question 1, this question was asked in order to learn more about food services in the Mina camps; 81 managers were eligible to answer this question as they all answered 'yes' or 'sometimes' for the first question while 22 managers were not asked this question. The response to this question is shown on **Figure 5-21**. This result indicates that if the camp manager provides food services, it is more likely that camp catering will provide the pilgrims with all three meals. From this, in addition to the result of question 1, it is known that 90% of the managers who provided food in their camps provided the pilgrims with all of their meals. However, 69 out of all 103 (67%) managers interviewed said that they always provided the pilgrims with food for all their meals every day in Mina.

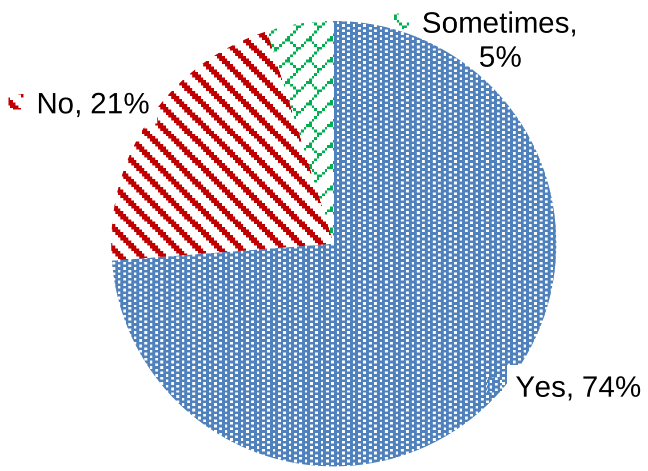

Figure 5-20 The answers to question 1 in the managers' questionnaire (Do you provide meals for the pilgrims in your camp?)

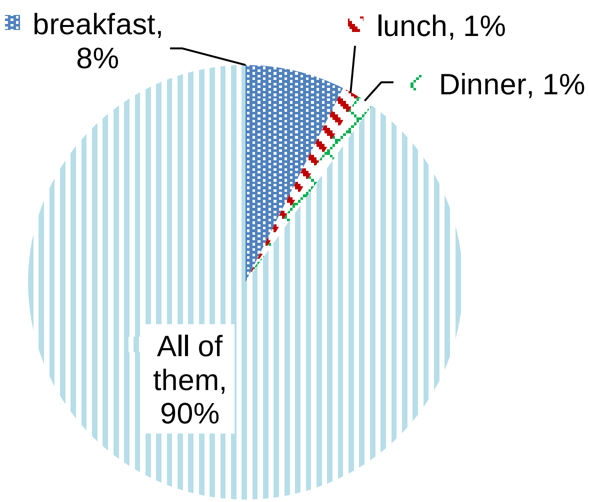

Figure 5-21 The answers to question 2 in the managers' questionnaire (Which meal do you provide?)

Question Three: ***What kind of meals do you provide in your camp?***

As for the previous question, this question was put only to the managers who provided meals to their pilgrims. The responses of the camp managers to this question are shown in **Figure 5-22**. From this figure, it can be seen that 42% of the managers could not determine the type of meals provided as they served only the food that was available whereas 43% of them succeeded in serving hot meals to their pilgrims. It is important to identify the reason for serving any available food to the pilgrims without any proper plan. The on-site observations showed that many camp managers were having problems with transporting food from outside Mina to their camps in Mina. This situation caused many managers to provide alternatives, such as buying different types of food from any food shops close to the camp, or asking some charity organizations to feed the pilgrims in their camp because of transportation problems (as was noticed, frequently, all cars were banned from entering Mina).

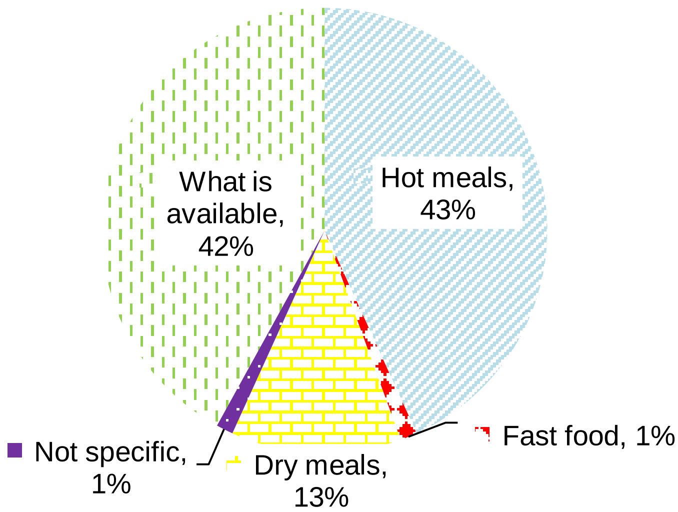

Figure 5-22 The answers to question 3 in the managers' questionnaire (What kind of meals do you provide in your camp?)

Question Four: ***Are there any places for selling food near to your camp?***

This question was asked to identify whether the pilgrims had other choices of food sources. The on-site observation showed that there was an abundance of food shops and street vendors. The managers' responses supported this, as about half of them saw a food supplier close to their camps (**Figure 5-23**). This means that the pilgrims might have consumed the food they bought, inside their camps which increased the waste generation. In addition, it indicates that the pilgrims might have thrown out the food provided to them by the camp catering and bought the food they preferred (**Figure 6-6**).

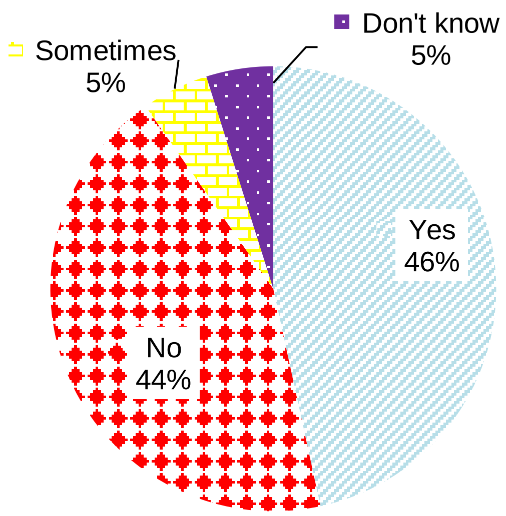

Figure 5-23 The answers to question 4 in the managers' questionnaire (Are there any places for selling food near to your camp?)

Question Five: ***What is the most common component in your camp's waste from your point of view?***

The answer to this question depended on the managers' point of view or opinion. Although subjective, it provides supportive evidence for the most common waste components in the Mina camps. The result of this question matched (to some extent) the result of the composition of the waste of the Mina camps (**Section 5-3-3**). Based on the camp managers' answers (**Figure 5-24**), the three top components were organic waste

(39%), plastic (39%), and paper and cardboard (10%). This order is consistent with the results of the composition of the camps' waste (by weight) (**Section 5-3-4, Table 5-7**). Again, plastic came first in the order of non-biodegradable waste components.

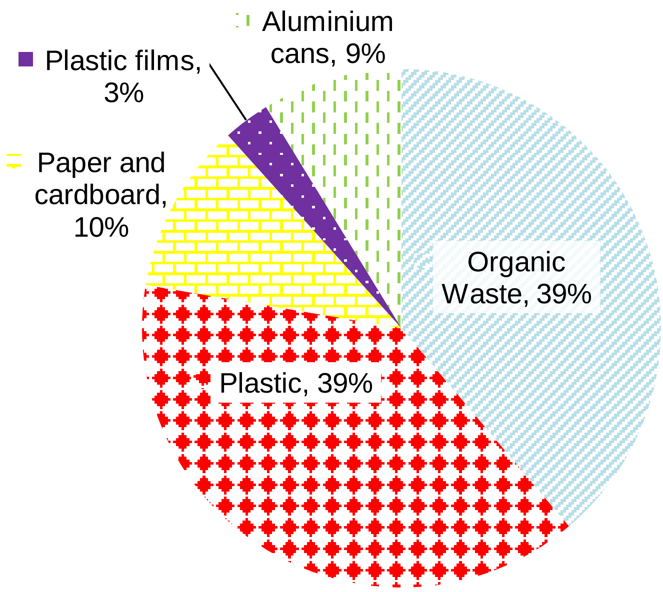

Figure 5-24 The answers to question 5 in the managers' questionnaire (What is the most common component in your camp's waste?)

Question Six: ***What do you do with the food residuals?***

This question aimed to discover if there were other methods used to handle the food residuals. Although it transpired that the majority of the camp managers (68%) disposed of the food residuals with their waste, about 30% of them took the effort of processing/selecting appropriate unused/leftover food in order to give it to the needy (**Figure 5-25**). These efforts should be generalized to other camps thus saving food and reducing the amount of waste.

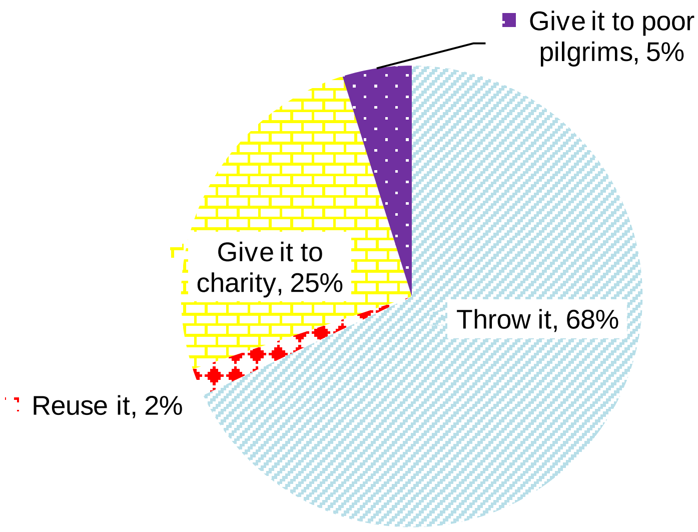

Figure 5-25 The answers to question 6 in the managers' questionnaire (What do you do with the food residuals?)

Question Seven: ***Do you support the idea of deriving a benefit from your waste?***

One of the most important goals of this questionnaire was to study the camp managers' ability to implement the waste source separation project in their camps during the Hajj. Thus, questions 7, 8 and 9 were asked. Question 7 was asked especially to check the managers' understanding of the process of waste sorting, as they may sell their sorted waste. The response to this question was positive, as 69% of the managers had an idea about such projects and supported the project (**Figure 5-26**). Thus, the implementation of the sorting project should not be difficult with most of the camp managers.

Question Eight: ***Are you going to support implementation of a waste sorting project in your camp?***

Although the positive responses regarding the understanding of this idea comprised 69% (question 7), the responses for applying a waste sorting project inside the Mina camps without any motivation were (to some extent) more negative, as 59% of the managers were unwilling to implement this project without any support or motivation (**Figure 5-27**). However, 19% of them agreed to implement this project whereas 22% of them said they might implement it. This means that almost 41% of the managers were willing and able to support this project without any motivation.

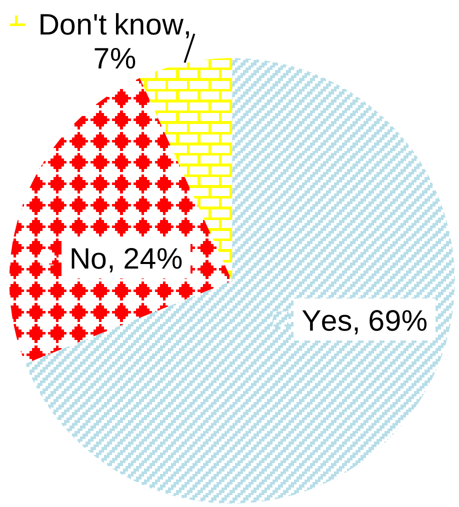

Figure 5-26 The answers to question 7 in the managers' questionnaire (Do you support the idea of deriving a benefit from your waste?)

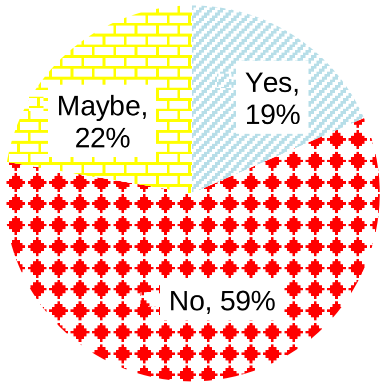

Figure 5-27 The answers to question 8 in the managers' questionnaire (Are you going to support implementation of a waste sorting project in your camp?)

Question Nine: ***If you found a buyer for the sorted waste in your camp, would you implement a sorting project in your camp?***

It is very obvious that the managers were motivated by money to implement a sorting project, as the positive possibility of implementing this project increased to 60% (yes + maybe) while the negativity decreased to 40% (**Figure 5-28**). Overall, these responses suggest that applying a camp-wide sorting project should not be optional but rather should be compulsory or with a good motivation (**Section 2-2-5**).

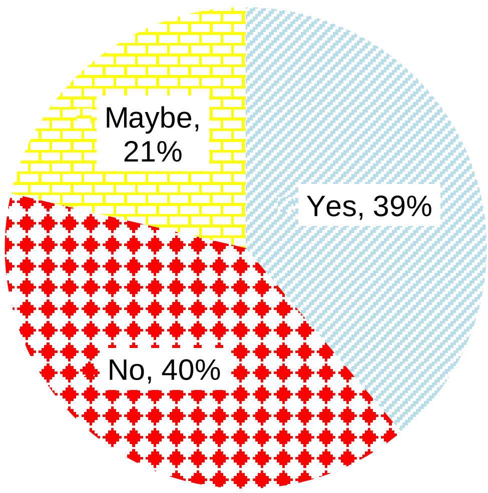

Figure 5-28 The answers to question 9 in the managers' questionnaire (If you found a buyer for the sorted waste in your camp, would you implement a sorting project in your camp?

Question Ten: ***What is the average cost for each pilgrim in your camp (SR)?***

The purpose of this question was to find any potential relationship between the cost and the manager's support for a waste sorting project. 7.8% (8 managers) of the managers refused to answer this question whereas many of the managers (95) who answered it tried not to give the real numbers (as was observed). The Ministry of Hajj (2011) stated that the cost of each pilgrim in Mina ranged from SR1,900 (£315) for just 22 camps in the low cost Hajj programme, to a maximum of SR22,000 (£3,700); however, 71% of the managers (67 managers) (**Figure 5-29**) said they took the minimum fees from the pilgrims (SR1,000 - SR2,000), which completely contradicts the Ministry's data. Thus, the results of this question were ignored and not used to interpret other data.

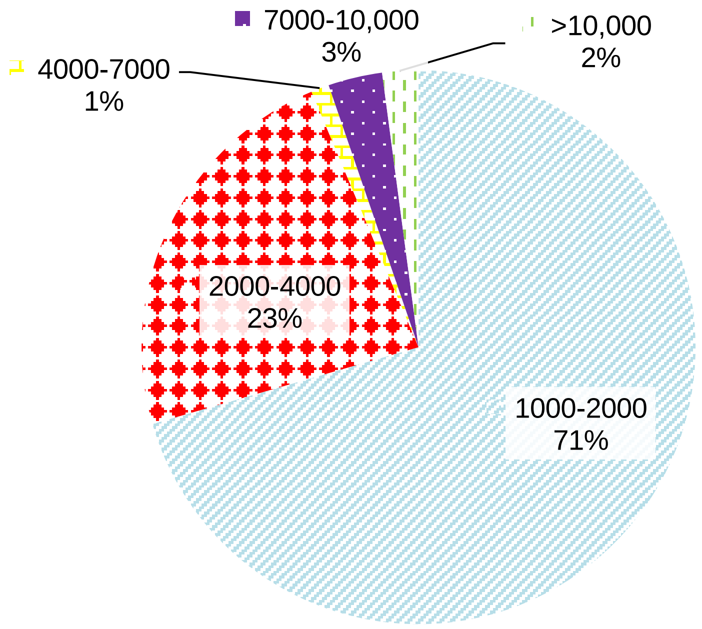

Figure 5-29 The answers to question 10 in the managers' questionnaire (What is the average cost for each pilgrim in your camp (SR)?)

5-5-1 Assessment of Compactor Boxes

Another important goal for this questionnaire was to assess what the users thought about the compactor boxes. Thus, the remainder of the managers' questionnaire (questions: 11, 12, 13, 14, 15 and 16) can be considered as a measurement of how useful the compactor box is from the perspective of the camp managers.

Question Eleven: ***Where do you dispose of your camp's waste?***

Although 87% of the interviewees said they disposed of their camp's waste in the compactor boxes (**Figure 5-30**), this answer is considered to be biased, as their fear of being fined (**Section 1-7-2**) was probably a reason for the high positive response of using the compactor boxes. However, the next questions will highlight some of the reasons why the managers failed to use these compactor boxes appropriately.

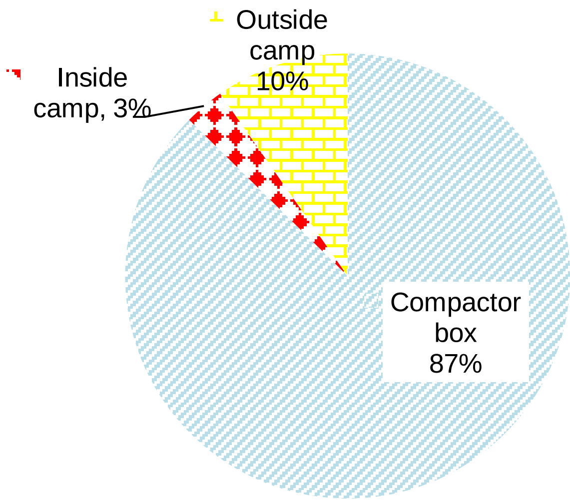

Figure 5-30 The answers to question 11 in the managers' questionnaire (Where do you dispose of your camp's waste?)

Question Twelve: ***Do you have waste compactor box in your camp?***

The results of this question should have been 100% positive, as the manager of the Mina area in Makkah Municipality stated that there was a compactor box for each camp in Mina (Alsebaei, 2010). However, 15% of the managers said they did not have a compactor box (**Figure 5-31**). This may be because the managers of these camps might not have been informed about the compactor boxes allocated to them. Alternatively, these camps may have had broken compactor boxes, so the managers considered that they did not have this service. This can be seen in the contradictory answers between this question and the previous question, where 11 managers (10.7%) said that they used compactor boxes to dispose their waste yet answered this question by saying that they did not have a compactor box. Similarly, nine managers (8.7%) said that they did not use the compactor boxes to dispose of their waste but stated that they had a compactor box, indicating they may have thrown their waste onto the streets.

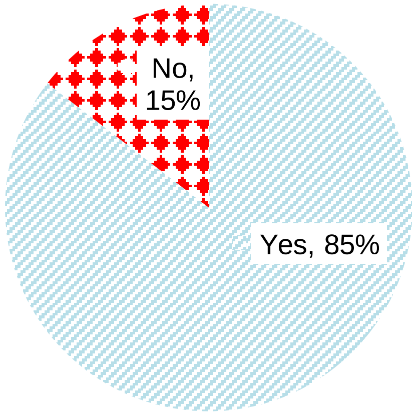

Figure 5-31 The answers to question 12 in the managers' questionnaire (Do you have waste compactor box in your camp?)

Question Thirteen: ***Do you think that one compactor box is enough for your camp?***

The aim of question 13 was to assess the capacity of the compactor box. As with the previous question, the managers who did not have a compactor box were asked to stop at this point; 88 managers answered this question and the following three questions. 55% of the responses were negative (**Figure 5-32**). This means these managers were looking for an alternative way to dispose of their waste after they had filled their compactor box, which might have made them throw their waste onto the street.

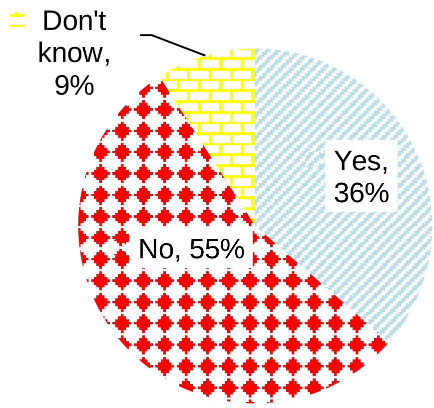

Figure 5-32 The answers to question 13 in the managers' questionnaire (Do you think that one compactor box is enough for your camp?)

Question Fourteen: ***Is it easy to reach the compactor box in your camp?***

The responses to this question show clearly that the location of the compactor boxes was not a problem for the Mina camp managers, as 93% of them said it was easy to reach the compactor box (**Figure 5-33**). Thus, the location of the compactor box cannot be taken as the reason for it not being used.

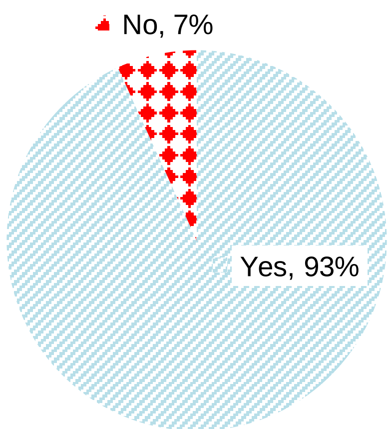

Figure 5-33 The answers to question 14 in the managers' questionnaire (Is it easy to reach the compactor box in your camp?)

Question Fifteen: ***If the compacting box is broken, is maintenance work carried out as soon as is appropriate?***

This can be one of the main causes of not using the compactor boxes, as about half of the managers said the maintenance was neither fast enough nor good enough (**Figure 5-34**). Thus, the maintenance procedure of these boxes needs to be reconsidered.

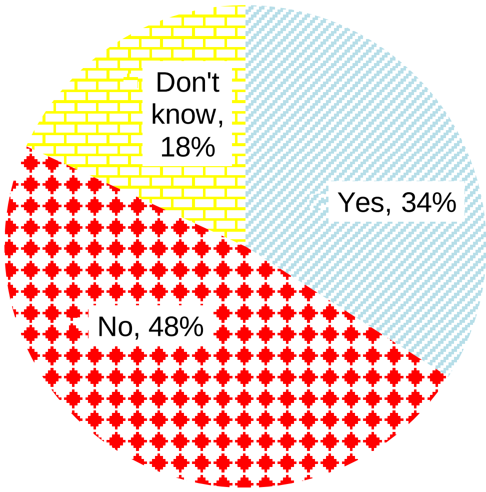

Figure 5-34 The answers to question 15 in the managers' questionnaire (If the compacting box is broken, is maintenance work carried out as soon as is appropriate?)

Question Sixteen: ***How many times a day is the waste collected and disposed of in the compacting box?***

As it is known that most of the compactor boxes were not used appropriately, the answer to this question could represent the frequency of waste collection and disposal in the camps but not the frequency of use of the compactor boxes. As shown in **Figure 1-22,** cleaning workers sometimes collected waste and disposed of it beside the compactor box. However, the responses generally show that the waste from the camps was collected on a frequency of three to more than four times a day (**Figure 5-35**).

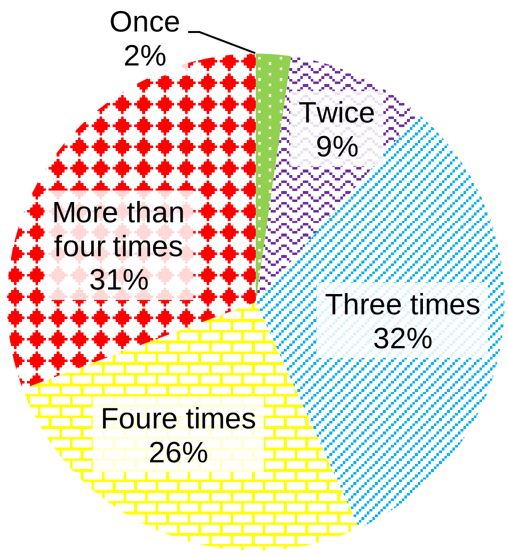

Figure 5-35 The answers to question 16 in the managers' questionnaire (How many times a day is the waste collected and disposed of in the compacting box?)

5-5-2 Summary of Camp Managers' Questionnaire Findings

Generally, the responses of the camp managers to the questions (which were to assess their performance) can be considered biased and subjective, as demonstrated by their answers to questions 10, 11, 15 and 16. However, their responses to the general information related to their camps seem more objective. For instance, the camp managers' opinions of the main waste components are consistent with the results of the composition of the camps' waste. Therefore, the camp managers' responses to the uses of the compactor boxes was considered as unreliable and biased, as their answers did not match the reality and the on-site observations, which was probably due to their fear of being fined. However, their assessment and their negative thoughts about these boxes can be taken into account, as there is no obvious reason for them to change the facts. For instance, one of the most important responses by the camp managers was that more than half of them thought that the capacity of one compactor box was not enough to accommodate all of their camp waste.

On the other hand, the managers' opinion about waste sorting and recycling seems to reflect their real feelings (as there is nothing to fear). Generally, about 70% of the camp managers supported the idea of recycling (though not necessarily in Mina), but it seems that they were afraid of implementing a waste sorting scheme at their camps, as their responses were more negative than definitely positive. However, the presence of some motivation (such as money) decreased their negative responses by about one-third of and almost doubled the definitely positive responses.

5-6 Pilgrims' Questionnaire

Despite the missing answers for some questions, a total of 903 forms were fully completed; each one represents one pilgrim. These 903 pilgrims represent 60 countries, which include all of the Tawafa companies except the Iran Tawafa Company which was excluded because of its limited number of pilgrims from the same country and the difficulty of communicating with them in their own language (**Table 5-26**). This table shows the number of completed forms per each country and its percentage; also, it illustrates three indicators for each country, namely, Gross Domestic Product (GDP) per capita ($), waste generation rate per capita ($kg.p^{-1}.year^{-1}$) and Environmental Performance Index (EPI) (**Section 4-8-3**).

In order to analyse the data of this questionnaire, these 60 countries were grouped into five different categories (**Table 5-27**). This distribution was based mainly on the similarities between countries, which is also the way that the Mina authorities divided the countries into Tawafa companies. Moreover, because there were only seven forms completed by pilgrims from the South East Asian Tawafa Company, this group was added to the group of the South Asian Tawafa Company (as it was the most similar group) to obtain a statistically sufficient groups. The new group was called the non-Arabic Asian countries. In addition, the group of Turkey and Muslims of Europe, the Americas and Australia Tawafa Company was renamed as the western countries group (as an abbreviation).

Table 5-26 Countries covered by pilgrims' questionnaire and their indicators (GDP per capita, EPI, and annual waste generation rate) that been used in the modelling

Tawafa Company	Country	No. of filled forms	Percentage %	GDP per capita ($)	EPI	Annual waste generation ($kg.p^{-1}$) Rate	Year	Reference
Saudi Arabia Pilgrims	Saudi Arabia	43	4.8	31800	49.97	474.5	2013	(MOMRA, 2013)
Arabian Countries Pilgrims	Egypt	76	8.4	6700	55.18	295.7	2009	(Al Sabbagh et al., 2012)
	Qatar	32	3.5	103900	46.59	474.5	2011	(GCC, 2013)
	Algeria	26	2.9	7600	48.56	242.2	2009	(Arif, 2010)
	Iraq	19	2.1	7200	25.32	317.6	2006	(Abou-Elseoud, 2008)
	Lebanon	19	2.1	16000	47.35	348.9	2009	(Arif, 2010)
	Syria	14	1.6	5100	42.75	204.6	2009	(Arif, 2010)
	Somalia	12	1.3	600	23	120.5	2011	(Collivignarelli et al., 2011)
	Sudan	12	1.3	2600	46	219	2006	(Abou-Elseoud, 2008)
	Yemen	12	1.3	2300	35.49	156.5	2009	(Arif, 2010)
	Jordan	11	1.2	6100	42.16	323.3	2011	(DOS, 2012)
	Kuwait	11	1.2	40500	35.54	511	2011	(GCC, 2013)
	Bahrain	10	1.1	29200	41.96	401.5	2009	(Al Sabbagh et al., 2012)
	Morocco	10	1.1	5400	45.76	157.2	2009	(Arif, 2010)
	Emirates	8	0.9	49800	50.91	474.5	2009	(Al Sabbagh et al., 2012)
	Tunisia	8	0.9	9900	46.66	218.5	2009	(Arif, 2010)
	Oman	4	0.4	29600	44	401.5	2011	(GCC, 2013)
	Mauritania	2	0.2	2200	33.7	136.4	2009	(Arif, 2010)
	Libya	1	0.1	12300	37.68	292	2005	(Hesnawi and Mohamed, 2013)
South Asian Pilgrims	Pakistan	174	19.3	2900	39.56	127.8	2009	(IUCN Pakistan, 2009)
	India	67	7.4	3900	36.23	135.1	2012	(Annepu, 2012)
	Nepal	32	3.5	1300	57.97	116.8	2011	(ADB, 2013)
	Bangladesh	8	0.9	2100	42.55	127.8	2013	(Karim, 2013)
	Afghanistan	2	0.2	1100	32.9	146	2006	(Visvanathan and Glawe, 2006)
South East Asian	Malaysia	3	0.3	17200	62.51	438	2010	(Moh and Abd Manaf, 2014)

Pilgrims	Indonesia	2	0.2	5100	52.29	254.4	2009	(Troschinetz and Mihelcic, 2009a)
	Philippines	1	0.1	4500	57.4	139.4	2009	(Troschinetz and Mihelcic, 2009a)
	Thailand	1	0.1	10300	59.98	240.9	2011	(PCD, 2012)
Non-Arab African Countries Pilgrims	Guinea	30	3.3	1100	44.4	87.6	2007	(Hoornweg and Bhada-Tata, 2012)
	Mali	27	3	1100	39.4	237.3	2007	(Samake et al., 2009)
	Ivory Coast	26	2.9	1800	53.55	175.2	2005	(Hoornweg and Bhada-Tata, 2012)
	Ghana	20	2.2	3400	47.5	186.2	2010	(Ofori-Boateng et al., 2013)
	Senegal	18	2	2100	46.73	189.8	2005	(Hoornweg and Bhada-Tata, 2012)
	Sierra Leone	16	1.8	1400	32.1	164.3	2004	(Sood, 2004)
	Congo	14	1.6	4700	47.18	193.5	2005	(Hoornweg and Bhada-Tata, 2012)
	Nigeria	11	1.2	2800	40.14	211.7	2009	(Babayemi and Dauda, 2009)
	Burkina Faso	10	1.1	1400	47.3	186.2	2005	(Hoornweg and Bhada-Tata, 2012)
	Cameroon	10	1.1	2400	42.97	290	2009	(Parrot et al., 2009)
	Gambia	10	1.1	1900	50.3	197.1	2011	(Bah, 2011)
	South Africa	8	0.9	11600	34.55	237.3	2011	(Guerrero et al., 2013)
	Chad	4	0.4	2000	40.8	182.5	2005	(Hoornweg and Bhada-Tata, 2012)
	Tanzania	3	0.3	1600	54.26	182.5	2011	(Guerrero et al., 2013)
	Comoros	2	0.2	1300	35	55	2004	(Payet et al., 2004)
	Ethiopia	2	0.2	1200	52.71	116.8	2011	(Guerrero et al., 2013)
	Niger	2	0.2	800	37.6	178.9	2005	(Hoornweg and Bhada-Tata, 2012)
	Angola	2	0.2	6500	47.57	118	2012	(Macauhub, 2012)
	Togo	2	0.2	1100	48.66	189.8	2005	(Hoornweg and Bhada-Tata, 2012)
	Benin	1	0.1	1700	50.38	197.1	2005	(Hoornweg and Bhada-Tata, 2012)
	Kenya	1	0.1	1800	49.28	190	2010	(Sira, 2010)
	Liberia	1	0.1	700	51	198	2008	(Milbrandt, 2009)
Turkey and Muslims of Europe, the Americas and Australia Pilgrims	UK	22	2.4	37500	68.82	423	2012	(DEFRA, 2013)
	Australia	17	1.9	43300	56.61	2200	2011	(Department of the Environment, 2013)
	USA	6	0.7	50700	56.59	726.4	2012	(USEPA, 2014a)
	France	5	0.6	36100	69	534	2012	(EUROSTAT, 2014)
	Tajikistan	4	0.4	2300	38.78	160	2011	(UNECE, 2012)
	Belgium	3	0.3	38500	63.02	456	2012	(EUROSTAT, 2014)
	Turkey	2	0.2	15200	44.8	390	2012	(EUROSTAT, 2014)
	Ireland	2	0.2	42600	58.69	623	2011	(EUROSTAT, 2014)
	Brazil	1	0.1	12100	60.9	311.7	2009	(Troschinetz and Mihelcic, 2009a)
	New Zealand	1	0.1	30200	66.05	575	2010	(Ministry for the Environment, 2011)

Table 5-27 The five categories (regrouped Tawafa companies) of the countries covered in the pilgrims' questionnaire

Group	**Count**	**Percentage (%)**
Saudi Arabia Tawafa Company	43	4.8
Arabian Countries Tawafa Company	287	31.8
South East Asia Tawafa Company + South Asia Tawafa Company	7 + 283	32.1
Non-Arab African countries Tawafa Company	220	24.3
Turkey and Muslims of Europe, the Americas and Australia Tawafa Company (Western countries group)	63	7.0

5-6-1 Pilgrims' Questionnaire Results

Education level

The responses to the level of education were as shown in **Figure 5-36**. **Figure 5-36** also illustrates that there were two main categories: the group of pilgrims who could read and those with a high school degree. However, the mode and median in this case was the high school degree category.

These seven categories are unbalanced because of the huge variance between them, which might have caused a problem in analysing data. Thus, these groups were re-categorised into four groups **(Table 5-28**).

Figure 5-37 illustrates a comparison between the level of education and the five groups of Tawafa companies. It is important to keep in mind that the variation in the level of education against Tawafa Company groups does not represent the level of education in the countries represented by each Tawafa Company but instead reflects the level of education for the pilgrims from these countries. For instance, although about 35% of the pilgrims in the Western countries group had no school degree, this does not reflect the percentage of people in these countries without a school degree.

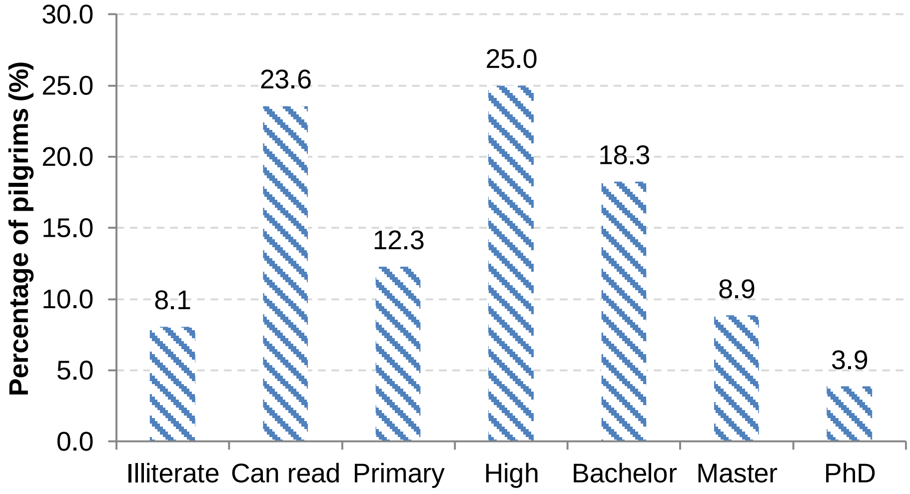

Figure 5-36 The percentage of the answers to the level of education for all pilgrims, where it can be seen that about 31% of the interviewed pilgrims had a university degree or more

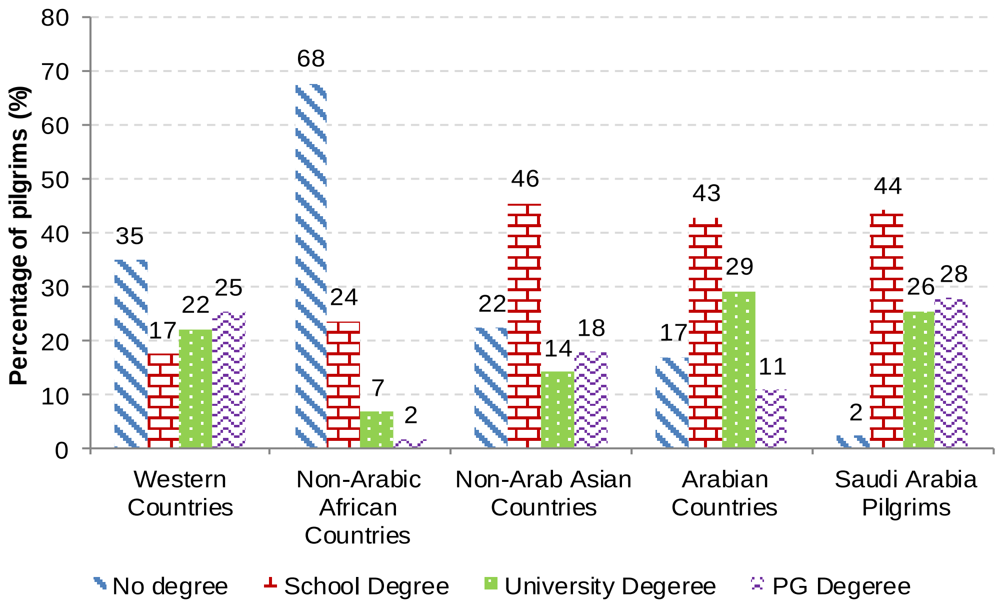

Figure 5-37 Level of education vs. regrouped Tawafa companies (pilgrims' questionnaire), which shows that most of the interviewed pilgrims from the non-Arabic African Tawafa Company had no school degree whereas Saudi Arabia's pilgrims had the highest percentage of postgraduate degrees

Table 5-28 Re-categorised level of education in four groups

Category	No degree	School degree	Bachelor degree	Postgraduate degree
It includes	Illiterate + can read	Primary + high school	Bachelor	Master degree + PhD
Count	286	337	165	115
Percentage	31.7	37.3	18.3	12.7

Question One: ***Do you eat in your Mina camp?***

This question focuses on the place of eating as a possible factor that could affect the level of waste sorting. There were three possible answers for this question: I always/ sometimes/ rarely eat in my camp. **Figure 5-38** shows the frequency of the answers (as a percentage) to this question**.** As this **Figure 5-38** shows, the mode of the answer was 'always' (48%) as almost half of the pilgrims never ate outside their camps. It can be concluded that most of the pilgrims (85%) had the habit of eating inside their camps.

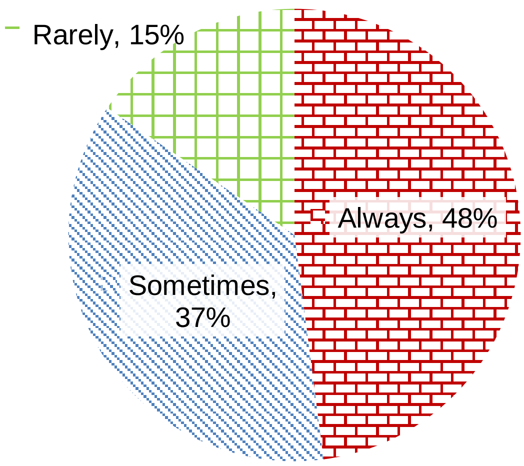

Figure 5-38 The answers to question 1 in the pilgrims' questionnaire (Do you eat in your Mina camp?)

To add the data to the econometric model, the answers were regrouped into two groups to differentiate between having the habit of eating inside the camp (even occasionally) or not. Thus, the first group represents the answers ‘always’ and ‘sometimes’ (85%) while the second group represents the answer ‘rarely’ (15%).

Question Two: ***From where do you get your food?***

This question was asked to identify the relationship between the food sources and the intention to separate waste. **Figure 5-39** shows the answers to this question as a percentage. About half of the pilgrims (48%) had their food from their camp’s catering (the mode). From this question and the question 1, it is concluded that 87% of pilgrims who answered ‘I always eat in my camp’, had their meal from the camp’s catering while 10% of them bought their own food. On the other hand, 14.3% of pilgrims bought their food and ate it in their camps while 47% of pilgrims did that occasionally.

However, responses to the first question in the managers’ questionnaire indicated that 74% of the camps provided the pilgrims with all their meals as part of the camp’s catering, but according to the pilgrims’ responses to this question, 48% of the pilgrims had all of their food from their camp’s catering, which means that the rest of the pilgrims were not satisfied with the type of food served to them. Thus, it is expected that some of the pilgrims threw away the food provided by the camp catering and bought their own (a real example for this situation can be seen in **Section 6-2-3, Figure 6-6**). This seems to have caused an increase in the amount of organic waste generated.

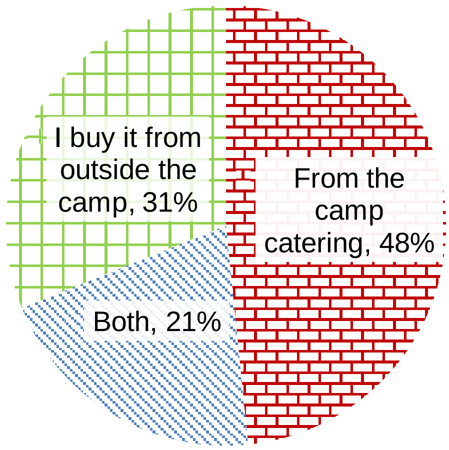

Figure 5-39 The answers to question 2 in the pilgrims' questionnaire (From where do you get your food?)

The answers to this question were also re-categorised into two categories (to be used in the econometric model) to differentiate between people who obtained all of their food from the camp catering and those who bought their own food. Thus, the first group represents the pilgrims who had all their food from their camp's catering (48%) whereas the second group represent pilgrims who bought all or part of their food (52%).

Question Three: ***Did you hear anything about waste sorting and recycling?***

The objective of this question was to identify the pilgrims' background regarding recycling based on use of the source separation process. **Figure 5-40** shows the pilgrims' responses to this question. The responses to this question showed that 34% of the pilgrims had no idea about recycling and sorting while 66% said they knew about it (the mode). This variance should be considered in the design of the source separation system as it might affect the response to the ‘intention to sort’ questions, which will be tested in the econometric model.

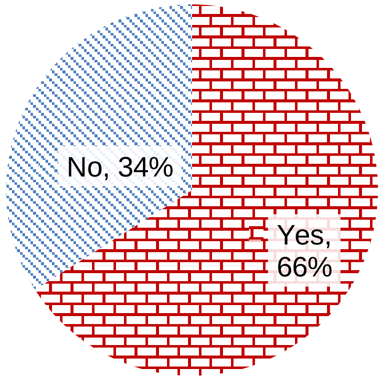

Figure 5-40 The answers to question 3 in the pilgrims’ questionnaire (Did you hear anything about waste sorting and recycling?)

Question Four: ***Having read the definitions, do you think you will be able to sort your solid waste?***

One objective of this question was to check if the pilgrims understood the definitions of sorting and recycling that were written on the questionnaire form and whether they would then have the knowledge to sort their waste. However, the main goal of this question was to test if short and simple descriptions of waste sorting at source and waste recycling can make pilgrims understand the importance of waste source separation and recycling and enhance their intention to sort (as will be tested in the econometric model, **Section 5-6-2**).

The responses to this question are shown in **Figure 5-41** where the answer ‘yes’ represents the mode (69%). From this question and question 3, it can be seen that 86.3% of the pilgrims who had heard about waste sorting and recycling knew how to sort their waste whereas 13.7% of them did not know what to do it even after reading the definitions. However, 17% of the pilgrims who said that they did not have a background of waste sorting and recycling decided that they could sort their waste after they had read the definitions. This means that some pilgrims will participate in a waste sorting and recycling project if they understand the concept. This concept can be delivered to pilgrims by educational programmes and information campaigns as shown in the literature review (**Section 2-3-4**).

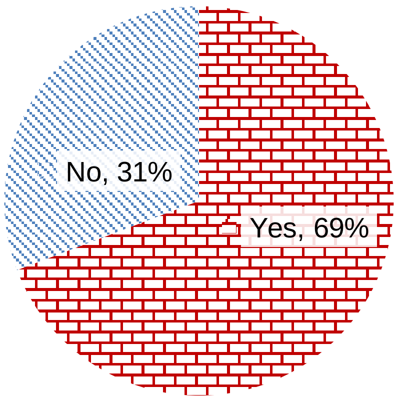

Figure 5-41 The answers to question 4 in the pilgrims' questionnaire (Having read the definitions, do you think you will be able to sort your solid waste?)

Question Five: ***Do you sort your solid waste at your home in your country?***

The previous two questions asked the pilgrims about their knowledge about recycling whereas this question asked about the actual behaviour or habit of waste source separation in their home country. **Figures 5-42** illustrates the percentage of the pilgrims' answers to this question, which shows that the mode of the question was negative (55%). However, the rest (45%) said they were practising waste sorting at home but there was great diversity regarding the nature of their sorting habit. For instance, some of the pilgrims explained to the interviewer that although their countries' government did not ask them to sort their waste, they would sort some of the important items of their waste (such as bottles) and sell such waste to people working in recycling (informal recycling in developing countries, **Section 2-5**). Thus, it can be said that there is a wide variety in the nature of the recycling habit (motivations and reasons) for this group.

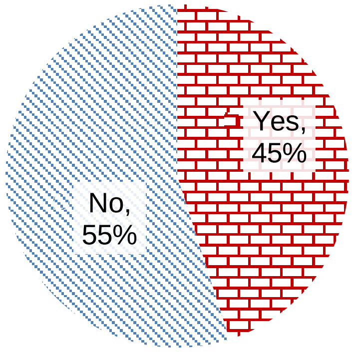

Figure 5-42 The answers to question 5 in the pilgrims' questionnaire (Do you sort your solid waste at your home in your country?)

Questions Six 1 and 2: ***If it is optional*** **OR** ***if it is compulsory*** **-** *Do you think you would sort your solid waste in your camp during the Hajj in Mina?*

These two questions were asked to measure the percentages of the pilgrims' intention to sort their waste at source with the options of 'definitely', 'maybe' or 'never' in the case of optional sorting or compulsory sorting (compulsory by law without defining any penalties). **Table 5-29** shows the frequencies of the answers for both questions (the mode of the both questions is 'yes'). Based on this table, it can be seen that the pilgrims' intention to sort their waste if sorting is compulsory is slightly more than for the optional sorting. However, when it was optional, people tended to answer 'maybe' more than when it was compulsory, in which case people preferred to say 'yes' or 'no'. Based on pilgrims' answers, 50% of pilgrims would sort their waste if sorting were option and 55% would do so if it were compulsory by law. These percentages could increase to 68% or more if pilgrims who said ‘maybe’ decided to sort all their waste in both cases.

Table 5-29 Frequencies of the answers to questions 6-1 and 6-2 in the pilgrims’ questionnaire

Answers		No	Maybe	Yes
Question 6-1	**Count**	274	180	449
	Percentage	30.3	20	49.7
Question 6-2	**Count**	294	116	493
	Percentage	32.6	12.8	54.6

The results for these two questions showed some contradictory outcomes. If a pilgrim answered ‘yes’ for the optional sorting, he/she was expected to answer ‘yes’ for the compulsory sorting. However, 87 pilgrims answered ‘yes’ for the optional sorting (question 6-1) but changed their answers to ‘maybe’ or ‘no’ for the compulsory sorting question (question 6-2) (**Figure 5-43**). It is unknown whether this conflict occurred because of carelessness in answering, because of a resistance to the notion of compulsion, or because of other unrecorded factors. Thus, the results of all 903 pilgrims' answers will be presented as well as the results of the 816 pilgrims (after eliminating the 87 forms that contained the contradictory answers). However, the model with the better McFadden pseudo R^2 was used to build the econometric model.

After removing the contradictory answers, the percentage of people who had a positive answer for optional waste sorting decreased to 44.4% whereas the percentage of the ‘yes’ answer in the compulsory waste sorting question increased to 60.4% (**Figure 5-44**).

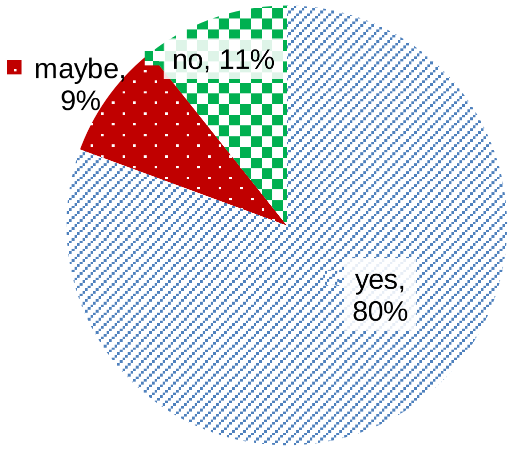

Figure 5-43 The answers of pilgrims who answered 'yes' in question 6-1 to question 6-2 (pilgrims' questionnaire)

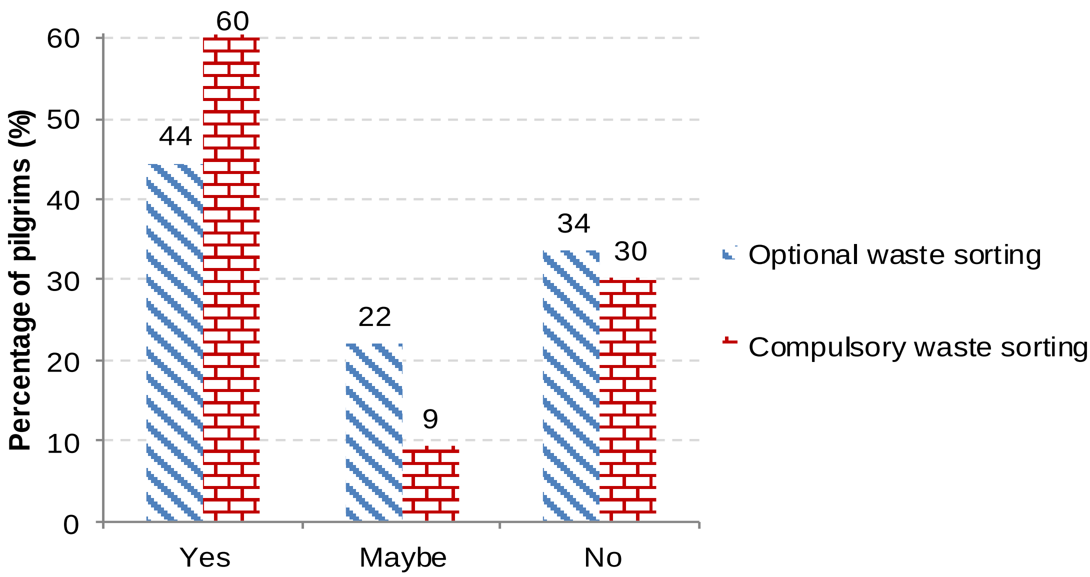

Figure 5-44 The pilgrims' answers to questions 6-1 and 6-2 in the pilgrims' questionnaire after removing the contradictory answers (If it is optional OR if it is compulsory - Do you think you would sort your solid waste in your camp during Hajj in Mina?)

As mentioned in **Section 2-3-4**, many researchers have reported a relationship between recycling intention and habit; thus, it was essential to compare pilgrims' stated sorting intention with their recycling habit. This was done through comparing the answers to both questions 6-1 and 6-2 with the answer to question 5 (**Figure 5-45**). Overall, it can be seen that the presence of a recycling habit increases the sorting intention especially when sorting is compulsory (**Section 7-2**).

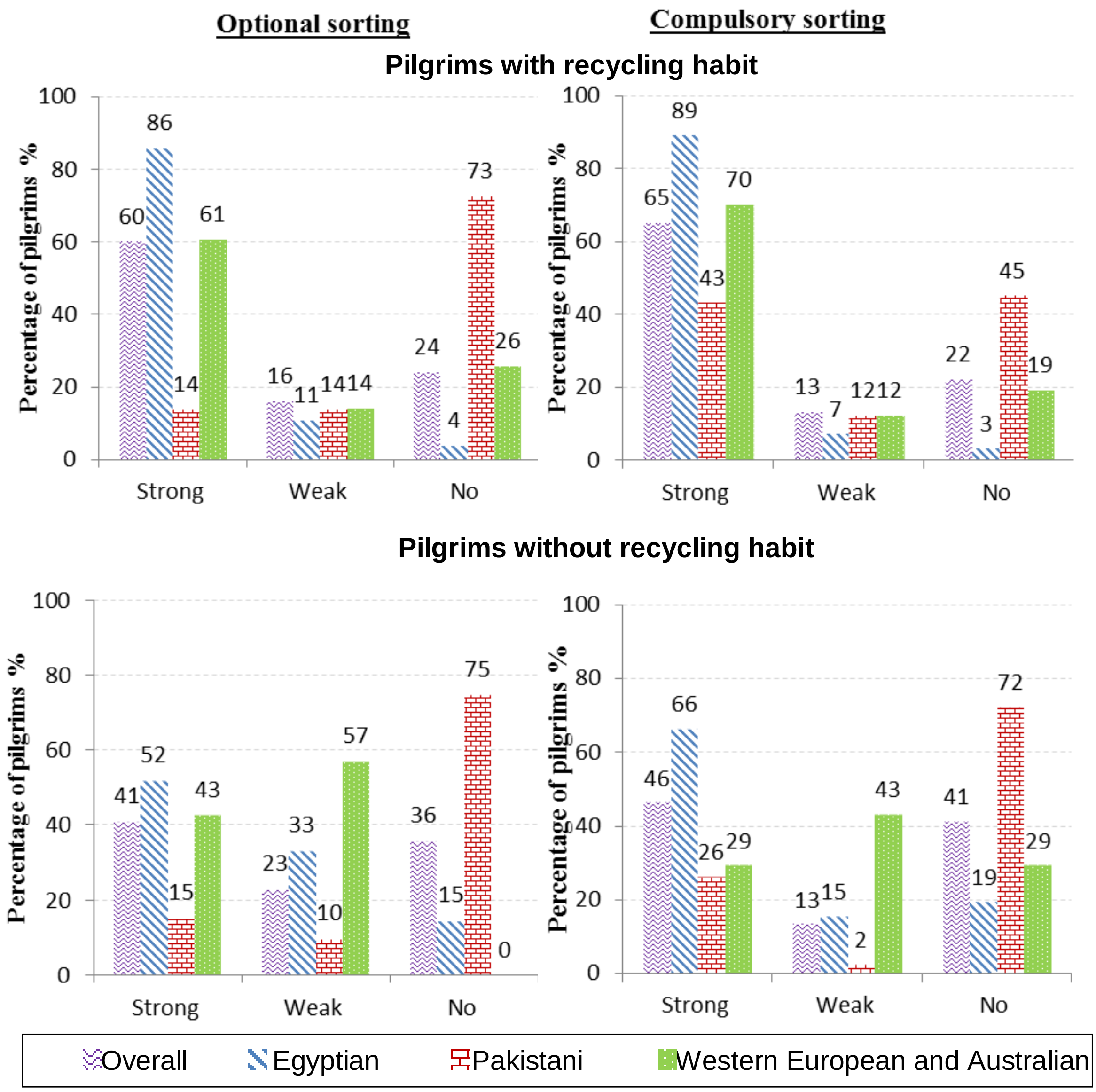

Figure 5-45 A comparison between the pilgrims' stated intention to sort their waste at their Mina camps (optionally and compulsory) and their habit of waste recycling in their home countries for the three groups of pilgrims tested in the exemplar project and the overall pilgrims

Question Seven: ***Are you satisfied about the level of cleanliness in Mina's streets during the Hajj?***

The goal of this question was to assess the level of cleanliness of Mina's streets from the pilgrims' perspective. **Figure 5-46** shows the frequencies of the answers (as percentages) for this question. It can be seen that the mode of the answers is 'satisfied', but overall, 38% of the pilgrims were not satisfied with the level of cleanliness in Mina's streets.

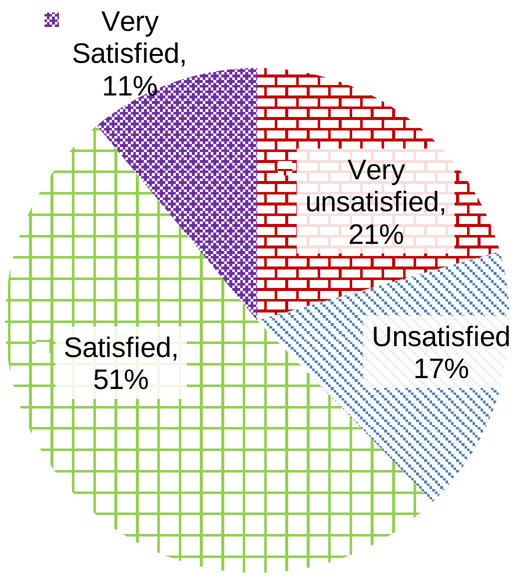

Figure 5-46 The answers to question 7 in the pilgrims' questionnaire (Are you satisfied about the level of cleanliness in Mina's streets during the Hajj?)

This factor can be added to the econometric model in two groups of answers: satisfied (very satisfied and satisfied) and unsatisfied (very unsatisfied and unsatisfied). This will make it easier to identify if people's intention to sort can be affected by the surrounding environment and cleanliness level.

Question Eight: Are you satisfied about the level of cleanliness in your Mina camp during the Hajj?

The aim of this question was to identify the pilgrims' level of satisfaction with the cleanliness level inside their camps. The percentages of the answers for this question are shown in **Figure 5-47**. It can be seen that the mode of the answers is 'satisfied', but overall, 40% of the pilgrims were not satisfied about the level of cleanliness in their Mina camp.

From this question and question 7, it can be concluded that 80% of pilgrims, who were unsatisfied (very unsatisfied + unsatisfied) about the level of cleanliness in their camps, were unsatisfied (very unsatisfied + unsatisfied) about the level of cleanliness in Mina's streets while 20% of them were satisfied (very satisfied + satisfied) about the level of cleanliness in Mina's streets. Moreover, 90.7% of the pilgrims who were satisfied (very satisfied + satisfied) about the level of cleanliness in their camps were satisfied (very satisfied + satisfied) about the level of cleanliness in Mina's streets while 9.3% of them were unsatisfied (very unsatisfied + unsatisfied) about the level of cleanliness in Mina's streets (**Figure 5-48**).

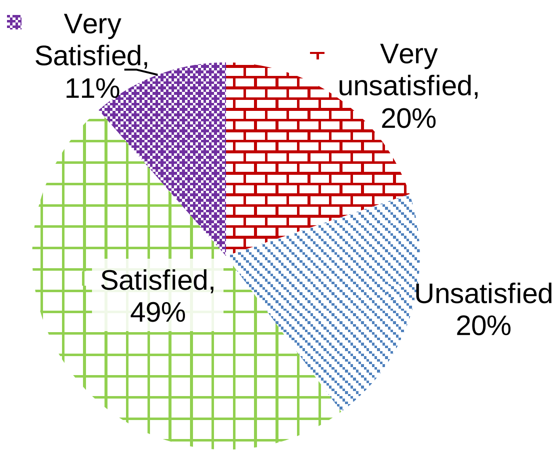

Figure 5-47 The answers for question 8 in the pilgrims' questionnaire (Are you satisfied about the level of cleanliness in your Mina camp during the Hajj?)

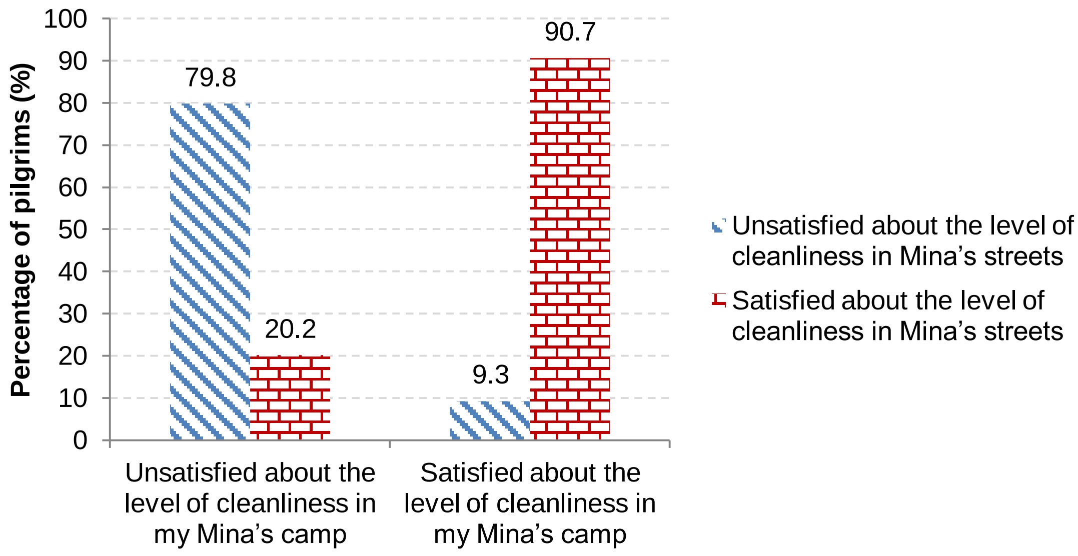

Figure 5-48 Comparison between pilgrims' level of satisfaction with cleanliness of Mina's streets and cleanliness of their Mina camps (pilgrims' questionnaire)

5-6-2 Factors Affecting the Pilgrims Intention to Sort their Waste

As mentioned in **Section 4-8-3,** the factors that affected the pilgrims' sorting intention can be derived from the econometric model. This model was built based on the results of the multinomial logistic regression. The dependent factors were first, Q6-1 and second, Q6-2, whereas the independent factors and the covariate in both cases were as follows:

1. GDP ($): Gross Domestic Product per capita (**Table 5-26**).
2. EPI: Environmental Performance Index (**Table 5-26**).
3. Waste Generation Rate per capita (**Table 5-26**).
4. The division of countries by the Mina authorities into Tawafa companies (**Table 5-27**).
5. Level of education (divided into four categories as shown in **Table 5-28**)

6. The responses to the questions of the pilgrims' questionnaire (**Section 5-6-1**). The responses to questions 1, 2, 7 and 8 were divided into two groups as mentioned previously.

Thus, the regression was done twice, first, to identify first those factors that affected the optional sorting intention (Q6-1) and second, to identify those factors that affected the compulsory sorting intention (Q6-2). The results of the regression gave three pseudo R^2 values: Cox and Snell, Nagelkerke, and McFadden (the value used in this research as explained in **Section 4-8-3**). The results also included two important tables: the first one gave each factor a p-value to indicate its level of statistical significance through the Likelihood ratio test, whereas the second table gave each category in each factor a p-value, value of effect (coefficient B), and sign of the effect (positive or negative) based on the reference category for each factor. These coefficients were considered as the econometric model's parameters if the p-values were significant (less than 0.05).

However, the parameters estimation table is divided into two parts (because Q6-1 and Q6-2 have three possible answers). The first part of the table is for the model's parameters for the answer ‘yes’ based on the answer ‘no’ as a reference whereas the second part is for the answer ‘maybe’ based on the reference. The second part of the table is not important because this research is looking for the factors that affect the sorting intention whereas it is difficult to consider the ‘maybe’ answer as a positive answer or as a negative answer. Thus, the econometric model will be estimated for the answer ‘yes’ only based on the answer ‘no’, which means the logit model equation used in this case is for binary not for multinomial.

Results of the optional sorting intention regression

As mentioned previously (**Section 5-6-1**), the results of all 903 completed forms are presented as well as the results of the 816 forms after eliminating the 87 forms that contained the contradictory answers for questions 6-1 and 6-2. **Table 5-30** shows the pseudo R^2 values of the multinomial logistic regression for the optional sorting model for results both of the group of all 903 forms and of the group of 816 forms, where it can be seen that McFadden pseudo R^2 value for the group of 816 forms is 0.263 (falls in the highly satisfactory zone, as detailed **Section 4-8-3**), which is bigger than the value of McFadden pseudo R^2 for the group of all 903 forms (0.238). This means that the model improved after the elimination of the 87 forms. Thus, the results of the group of 816 forms will be used in the comparison between the intention of pilgrims to sort their waste optionally and the sorting project results (exemplar project). Moreover, **Table 5-31** shows the results of the Likelihood ratio test, where it is clear that all the factors included in this model significantly affected the optional waste sorting intention except questions 2 and 8.

Table 5-30 Pseudo R^2 values for optional sorting model

	903 forms	**816 forms**
Pseudo R^2	**Value**	**Value**
Cox and Snell	0.388	0.427
Nagelkerke	0.444	0.486
McFadden	0.238	0.263

Table 5-31 Likelihood ratio test for optional sorting model

	903 forms		816 forms	
Effect	**-2 Log Likelihood of Reduced Model**	**p-value**	**-2 Log Likelihood of Reduced Model**	**p-value**
Intercept	1234.154	.	1113.775	.
GDP per capita	1263.934	0.000	1146.109	0.000
EPI	1241.895	0.021	1124.361	0.005
Waste generation	1244.716	0.005	1124.459	0.005
Level of education	1249.707	0.016	1176.692	0.000
Tawafa companies	1315.979	0.000	1130.759	0.009
First question: eating location	1249.313	0.001	1124.388	0.005
Second question: food source	1236.903	0.253	1115.940	0.339
Third question: recycling background	1264.146	0.000	1142.414	0.000
Fourth question: ability to sort	1245.371	0.004	1129.227	0.000
Fifth question: habit of sort	1241.904	0.021	1125.066	0.004
Seventh question: level of satisfaction with cleanliness of Mina's streets	1242.157	0.018	1123.373	0.008
Eighth question: level of satisfaction with cleanliness of Mina camp	1237.985	0.147	1116.161	0.303

Table 5-32 shows the optional sorting model's parameters estimation for the 'yes' answer only whereas the parameters of the 'maybe' answer are shown in **Table B1 (Appendix B)**. From this table, it can be seen that the relationship between the three countries indicators (GDP per capita, EPI, and waste generation per capita) and the optional intention to sort is significant and positive. In addition, in the level of education factor, the postgraduate group had more intention to sort optionally than the other three groups despite the insignificant difference between the group of pilgrims with no degree and the university degree group, which might be due to interaction with another

unrecorded factor. Thus, the relationship between intention to sort optionally and the level of education groups needs to be studied and investigated more in future research.

In terms of dividing countries into Tawafa companies groups, it is obvious from **Table 5-32** that the Arabian countries Tawafa Company had the most potential to sort waste optionally compared to the other companies. However, there was no significant difference between the Saudi Arabia pilgrims Tawafa Company and the Arabian countries Tawafa Company; thus, these two companies may have given better results than the others in terms of the optional waste sorting at source project.

Table 5-32 also shows that there is a relationship between food services and the pilgrims' willingness to sort their waste. So the pilgrims tended to sort more if they ate in their camps (first question) and if they bought their food, as the pilgrims might have felt responsible for the food they had bought (second question).

Another important factor that affected the pilgrims' intention to sort was their waste sorting and recycling background. Thus, a pilgrim with a sorting background (questions 3, 4 and 5) had more intention to sort his waste than had a pilgrim who did not have any idea about this subject.

The last factor that had a significant effect on the pilgrims' willingness to sort their waste at source was the level of cleanliness of Mina's streets. It was shown that the pilgrims who were satisfied (about the level of cleanliness) had more intention to sort their waste than had unsatisfied pilgrims. However, this was not applicable to the level of satisfaction with their camp's level of cleanliness.

Table 5-32 The optional sorting model's parameters estimation (for 'yes' answer)

Factors	903 forms			816 forms		
	B	Std. Error	p-value	B	Std. Error	p-value
Intercept	-3.472	0.986	0.000	-4.505	1.121	0.000
Countries indicators						
GDP per capita	0.000	0.000	0.000	0.000	0.000	0.000
EPI	0.037	0.014	0.006	0.047	0.015	0.001
Waste Generation rate	0.002	0.001	0.048	0.003	0.002	0.050
Level of education						
Post graduate degree	0.807	0.355	0.023	1.019	0.371	0.006
University degree	-0.114	0.316	0.719	0.141	0.334	0.672
School degree	0.480	0.266	0.071	0.622	0.282	0.027
No degree	0	.	.	0	.	.
Tawafa Company						
Western countries	-1.495	0.633	0.018	-1.935	0.666	0.004
Non-Arab African countries	0.657	0.580	0.258	0.127	0.652	0.845
Non-Arab Asian	-1.256	0.596	0.035	-1.113	0.682	0.102
Arabian countries	0.361	0.504	0.474	0.243	0.544	0.655
Saudi Arabia pilgrims	0	.	.	0	.	.
Q1- Do you eat in your Mina camp?						
Always + sometimes	1.193	0.319	0.000	1.091	0.346	0.002
Rarely	0	.	.	0	.	.
Q2- From where do you get your food?						
Camp catering	-0.363	0.220	0.099	-0.342	0.236	0.148
Buy it + both	0	.	.	0	.	.
Q3- Did you hear anything about waste sorting and recycling?						
Yes	1.332	0.247	0.000	1.412	0.268	0.000
No	0	.	.	0	.	.
Q4- Having read the definitions, do you think you will be able to sort your solid waste?						
Yes	0.923	0.277	0.001	1.168	0.303	0.000
No	0	.	.	0	.	.
Q5- Do you sort your solid waste at your home in your country?						
Yes	0.446	0.232	0.054	0.552	0.244	0.024
No	0	.	.	0	.	.
Q7- Are you satisfied about the level of cleanliness in Mina's steers during the Hajj?						
Unsatisfied	-0.461	0.277	0.096	-0.811	0.315	0.010
Satisfied	0	.	.	0	.	.
Q8- Are you satisfied about the level of cleanliness in your Mina camp during the Hajj?						
Unsatisfied	-0.440	0.272	0.105	-0.181	0.310	0.558
Satisfied	0	.	.	0	.	.

Results of the compulsory sorting intention regression

Table 5-33 shows the pseudo R^2 values for the compulsory sorting model for all 903 completed forms of the pilgrims' questionnaire as well as the results of the 816 forms. From **Table 5-33**, it can be seen that, again, McFadden pseudo R^2 value (0.295) for the 816 forms is bigger than McFadden pseudo R^2 for the 903 forms (0.258) and (also) bigger than both values of McFadden pseudo R^2 in the optional sorting model. In addition, since the literature review proved that the waste sorting project should be compulsory (**Section 2-2-5**), the econometric model (**Equation 4-4**) is going to estimate for the compulsory sorting model, for the 816 forms which had the biggest pseudo R^2 values over all four models' results. However, the results of both compulsory models are going to be presented.

Table 5-33 Pseudo R^2 values for compulsory sorting model

	903 forms	**816 forms**
Pseudo R^2	**Value**	**Value**
Cox and Snell	0.390	0.408
Nagelkerke	0.457	0.491
McFadden	0.258	0.295

In terms of the factors that affected the pilgrims' intention to sort their waste if they were forced to do so by law, Likelihood ratio tests for both models (**Table 5-34**) showed that all the factors significantly affected the pilgrims' sorting willingness except the waste generation rate in the 903 forms model and question 8 in the pilgrims' questionnaire in both models. From this result, it can be concluded that the factors that affected the pilgrims' intention to sort their waste optionally were not the same as the factors that affected the compulsory sorting.

Table 5-34 Likelihood ratio test for compulsory sorting model

Effect	903 forms -2 Log Likelihood of Reduced Model	p-value	816 forms -2 Log Likelihood of Reduced Model	p-value
Intercept	1182.557	.	945.310	.
GDP per capita	1197.391	0.001	966.729	0.000
EPI	1199.333	0.000	953.385	0.018
Waste generation	1186.925	0.113	956.836	0.003
Level of education	1201.903	0.004	989.268	0.000
Tawafa companies	1265.083	0.000	960.532	0.019
First question: eating location	1203.809	0.000	964.032	0.000
Second question: food source	1208.974	0.000	964.237	0.000
Third question: recycling background	1203.839	0.000	976.640	0.000
Fourth question: ability to sort	1196.245	0.001	958.712	0.001
Fifth question: habit of sort	1195.723	0.001	954.014	0.013
Seventh question: level of satisfaction with cleanliness of Mina’s streets	1210.291	0.000	962.655	0.000
Eighth question: level of satisfaction with cleanliness of the Mina camp	1185.108	0.279	946.663	0.508

However, the estimations of the compulsory sorting models’ parameters are shown in **Table 5-35** for the ‘yes’ answer while **Table B2** (**Appendix B**) shows the parameters for the ‘maybe’ answer. From **Table 5-35** for the 816 forms model, it can be seen also that all three countries indicators affected the compulsory waste sorting positively, which confirms that socio-demographic indicators have an effect on waste sorting intention.

Table 5-35 The compulsory sorting model's parameters estimation

Factors	903 forms			816 forms		
	B	Std. Error	p-value	B	Std. Error	p-value
Intercept	-3.146	0.904	0.000	-4.029	1.152	0.000
Countries indicators						
GDP per capita	0.000	0.000	0.000	0.000	0.000	0.000
EPI	0.050	0.013	0.000	0.040	0.015	0.006
Waste generation rate	0.001	0.001	0.065	0.005	0.002	0.018
Level of education						
Post graduate degree	1.049	0.343	0.002	0.819	0.373	0.028
University degree	0.834	0.302	0.006	0.766	0.339	0.024
School degree	0.745	0.245	0.002	0.590	0.273	0.031
No degree	0	.	.	0	.	.
Tawafa Company						
Western countries	-2.196	0.624	0.000	-1.580	0.669	0.018
Non-Arab African countries	-1.445	0.552	0.009	0.048	0.699	0.945
Non-Arab Asian	-1.534	0.555	0.006	-0.583	0.752	0.438
Arabian countries	-.161	0.509	0.751	0.467	0.587	0.427
Saudi Arabia pilgrims	0	.	.	0	.	.
Q1- Do you eat in your Mina camp?						
Always + sometimes	1.370	0.305	0.000	1.359	0.318	0.000
Rarely	0	.	.	0	.	.
Q2- From where do you get your food?						
Camp catering	-0.838	0.215	0.000	-0.838	0.240	0.000
Buy it + both	0	.	.	0	.	.
Q3- Did you hear anything about waste sorting and recycling?						
Yes	1.018	0.234	0.000	1.373	0.252	0.000
No	0	.	.	0	.	.
Q4- Having read the definitions, do you think you will be able to sort your solid waste?						
Yes	0.912	0.248	0.000	0.806	0.279	0.004
No	0	.	.	0	.	.
Q5- Do you sort your solid waste at your home in your country?						
Yes	0.772	0.215	0.000	0.680	0.241	0.005
No	0	.	.	0	.	.
Q7- Are you satisfied about the level of cleanliness in Mina's steers during the Hajj?						
Unsatisfied	-1.247	0.277	0.000	-1.153	0.310	0.000
Satisfied	0	.	.	0	.	.
Q8- Are you satisfied about the level of cleanliness in your Mina camp during the Hajj?						
Unsatisfied	0.278	0.264	0.293	0.167	0.303	0.582
Satisfied	0	.	.	0	.	.

Since this model is based on question 6-2 (waste sorting forced by law), it can be seen that the level of education is a significant factor that affects sorting intention. In addition, there are significant differences between the four categories of this factor where the postgraduate group has a greater potential to sort than have other groups; this potential gradually decreases as the level of education decreases. Thus, a higher level of education means a higher intention to sort waste at source if it is required by law (**Figure 5-49**). From this result and the result of the optional sorting model (**Table 5-32**), it seems that there is an interaction between the level of education and the following of the rules being a legal requirement.

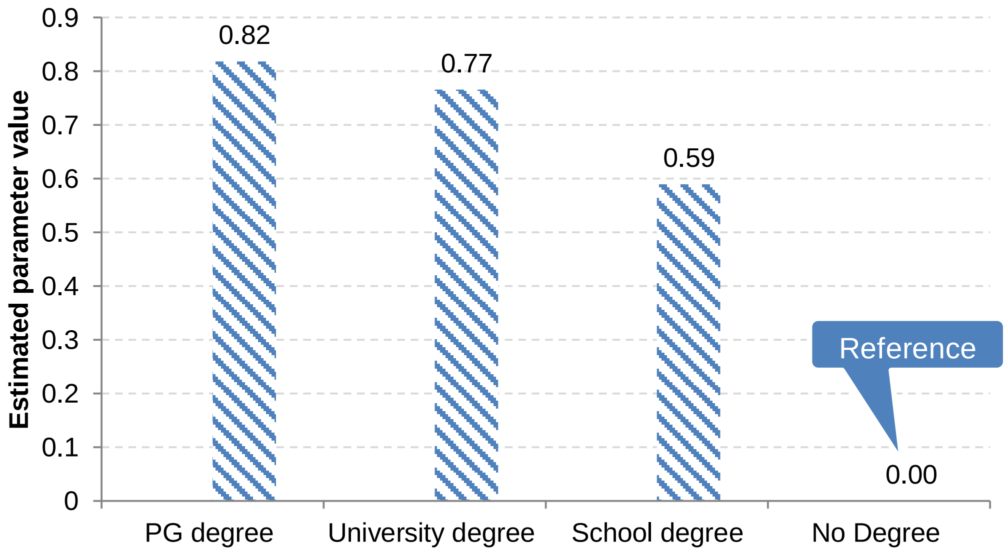

Figure 5-49 Level of education parameters' value for compulsory sorting (816 forms), where it can be seen that pilgrims with a higher level of education had more positive intention to sort compulsory (Reference point is explained in **Section 5-6-2**)

In terms of which country's pilgrims had the greatest intention to sort their waste if it were obligatory, it was found that the pilgrims from Saudi Arabia and the Arabian countries had more intention to sort than had the other pilgrims. However, there was no significant difference between these pilgrims' intentions and the intentions of the pilgrims from non-Arabic Asian and African countries. Thus, the only significant difference was between the western countries group and the other groups, which might be for the reasons explained previously in the optional model. In addition, the relationship between the questions and the intention to sort if it is compulsory is similar to the optional sorting mentioned previously.

The parameters used to build the logit model were derived from **Table 5-35** (from the section using the 816 forms), which had significant p-value (> 0.05). This means that there were significant differences between the parameters and their reference point, which equalled zero (**Table 5-36**). **Table 5-36** summarizes these significant parameters, which are included in the logit model for compulsory waste sorting for pilgrims who answered 'yes' for sorting compared to pilgrims who answered 'no'.

Based on **Table 5-36** and **Equations 4-4** and **4-5** (**Section 4-8-3**) the logit model equals to:

$$Z_i = \{-4.029 + 0.04X_2 + 0.005X_3 + 2.175X_4 - 1.58X_5 + 1.359X_6 - 0.838X_7 + 1.373X_8 + 0.806X_9 + 0.68X_{10} - 1.153X_{11}\}$$

$$P_i = \frac{1}{1 + e^{-Z_i}}$$

This model can be used in future research as it can predict the probability of pilgrims' positive sorting intention when all of the variables included are known. However, it cannot be used with the data collected in this research as it was used to build the model.

Table 5-36 The logit model summarized parameters, which were used to formulate the logit model by **Equations 4-4** and **4-5**

Parameter	**B**	**Std. Error**	**p-value**
Intercept (β_1)	-4.029	1.152	0.000
GDP per capita (β_2 X_1)	0.000	0.000	0.000
EPI (β_3 X_2)	0.040	0.015	0.006
Waste Generation (β_4 X_3)	0.005	0.002	0.018
Level of education (β_5 X_4) = (2.175 X_4)			
Post graduate degree	0.819	0.373	0.028
University degree	0.766	0.339	0.024
School degree	0.590	0.273	0.031
No Degree	0	.	.
Tawafa Company (β_6 X_5) = (-1.58 X_5)			
Western countries	-1.580	0.669	0.018
Non-Arab African countries	0.048	0.699	0.945
Non-Arab Asian	-0.583	0.752	0.438
Arabian countries	0.467	0.587	0.427
Saudi Arabia pilgrims	0	.	.
Q1- Do you eat in your Mina camp? (X_6)			
Always + sometimes (β_7 X_6)	1.359	0.318	0.000
Rarely	0	.	.
Q2- From where do you get your food? (X_7)			
Camp catering (β_8 X_7)	-0.838	0.240	0.000
Buy it + both	0	.	.
Q3- Did you hear anything about waste sorting and recycling? (X_8)			
Yes (β_9 X_8)	1.373	0.252	0.000
No	0	.	.
Q4- Having read the definitions, do you think you will be able to sort your solid waste? (X_9)			
Yes (β_{10} X_9)	0.806	0.279	0.004
No	0	.	.
Q5- Do you sort your solid waste at your home in your country? (X_{10})			
Yes (β_{11} X_{10})	0.680	0.241	0.005
No	0	.	.
Q7- Are you satisfied about the level of cleanliness in Mina's steers during the Hajj? (X_{11})			
Unsatisfied (β_{12} X_{11})	-1.153	0.310	0.000
Satisfied	0	.	.

5-6-3 The Prediction of the Future Behaviour from the Stated Intention

According to the methodology detailed in **Section 4-10** and based on Fujii and Gärling (2003) findings about predicting future behaviour from the stated intention, **Table 5-37** shows the expected future behaviour based on the stated intention for the three nationalities groups (selected in the exemplar project) as well as for all the overall pilgrims who participated in the questionnaire. **Figure 5-50** summarises the expected percentage of pilgrims who would sort their waste based on their stated intention for the two scenarios (if pilgrims have a recycling habit or if pilgrims do not have a recycling habit)

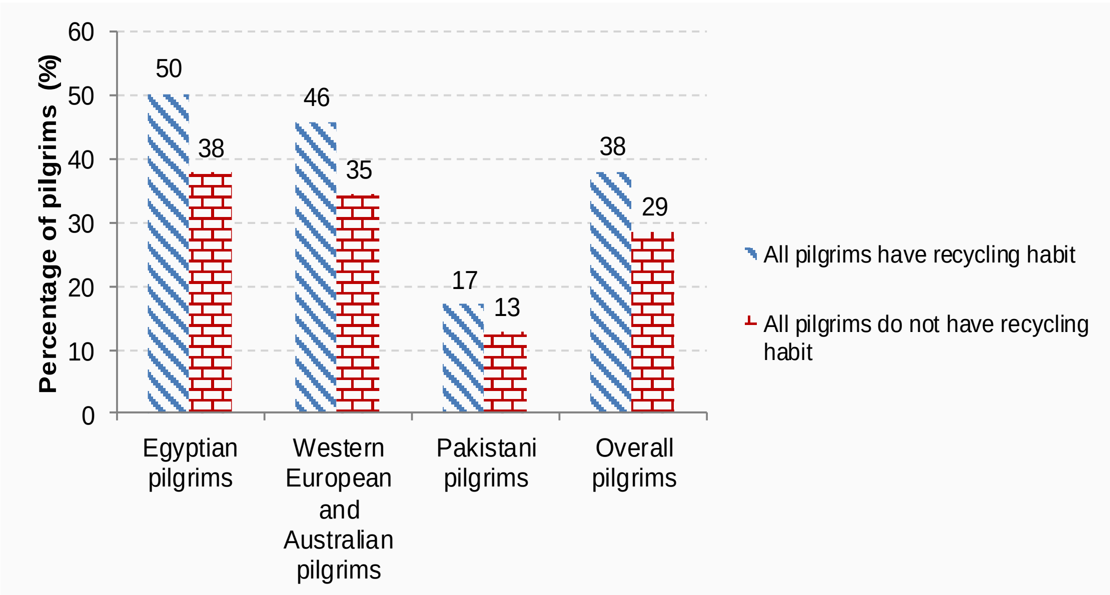

Figure 5-50 The expected percentage of pilgrims expected to sort their waste at their Mina camps based on their stated intention for both scenarios of pilgrims' recycling habit, for the three nationality groups (in the exemplar project) and the overall pilgrims in the pilgrims' questionnaire

Table 5-37 The estimation of the pilgrims' future recycling behaviour from their stated intention, based on Fujii and Gärling (2003) findings of predicting future behaviour from stated intention detailed in **Section 4-10**

Nationalities	**Egypt**	**Western Europe and Australia**	**Pakistan**	**Overall the questionnaire**
The size of the sample (N)	72	50	174	816
Number of people who answered 'yes' (strong intention)	45	29	26	362
Number of people who answered 'maybe' (weak intention)	19	10	19	180
Number of people who answered 'no' (no intention)	8	11	129	274
First scenario (All pilgrims have recycling habit)				
Number of pilgrims who had strong intention and are expected to participate in recycling (65%)	29.25	18.85	16.9	235.3
Number of pilgrims who had weak intention and are expected to participate in recycling (35%)	6.65	3.5	6.65	63
Number of pilgrims who had no intention and are expected to participate in recycling (5%)	0.4	0.55	6.45	13.7
Total number of pilgrims who were expected to participate in sorting based on stated intention	36.3	22.9	30	312
Percentage of pilgrims who are expected to perform sorting at their camps	**50.4**	**45.8**	**17.2**	**38.2**
Second scenario (All pilgrims do not have recycling habit)				
Number of pilgrims who had strong intention and were expected to participate in recycling (49%)	22.05	14.21	12.74	177.38
Number of pilgrims who had weak intention and were expected to participate in recycling (26%)	4.94	2.6	4.94	46.8
Number of pilgrims who had no intention and were expected to participate in recycling (3.8%)	0.304	0.418	4.902	10.412
Total number of pilgrims who were expected to participate in sorting based on stated intention	27.3	17.2	22.6	234.6
Percentage of pilgrims who were expected to perform sorting at their camps	**37.9**	**34.5**	**13.0**	**28.7**

5-6-4 Summary of Pilgrims' Questionnaire Findings

Although the Mina community consists of pilgrims from 181 countries, the factors that affected individual sorting in most communities did affect the pilgrims' intention in Mina. These factors are level of education, social level (represented be GDP per capita, EPI, and the annual waste arising per capita), ethnicity, waste sorting and recycling background and habit, and information campaigns and educational programmes. In addition, there are other factors especially for the case of Mina: the method of food catering inside the Mina camp and the pilgrims' satisfaction with the level of cleanness of Mina's streets. However, because of this immense mix of cultures, some of these factors need to be studied furthermore. For instance, the nature of the recycling habit needs to be identified for each group of pilgrims as the motivations and reasons for the recycling habit are not the same for each group of pilgrims.

5-7 Summary of the Primary Results Leading to the Next Chapter

The overall objective of this chapter was to build a background about the current SWM system in Mina combined with feedback from the service consumers and providers (pilgrims, camps managers, and the Mina authorities). This helped to identify the problems associated with this system and prepare for testing an alternative through an exemplar project implemented in accordance with the methodology (**Chapter 4**).

Based on results of the Wasteaware ISWM benchmark indicators for Mina, it was found that there were four major problems with SWM in Mina: waste disposal, recycling, no clear legislation for SWM in Mina, and pilgrims not being involved in SWM planning. Furthermore, the camp managers were not fully satisfied with the method of waste disposal in their camps (compactor boxes) while about 40% of the pilgrims were not satisfied with this system. Thus, the importance of implementing an alternative waste disposal method (such as recycling) in this system appeared.

As mentioned in **Section 2-2**, for a recycling system to be successful, waste should be sorted at the source of generation. The simplest method of doing this is to use a single stream recycling method with one material only (as Mina is a very busy area). Based on the results for the composition of waste from the Mina camps (**Section 5-3-4**) and the feedback from camp managers (**Section 5-5**), plastic is the most frequent component of the non-biodegradable waste in the Mina camps (representing about one-third of camp waste) and the one of the most feasible material to recycle (**Section 2-3-2**).

Although the plastic waste generated in Mina's camps consists of many plastic components, this enormous quantity of plastic should not be wasted. In 2010, it was estimated that more than half metric ton of plastic was disposed of in the Mina camps' compactor boxes (**Table 5-7**). However, on a bigger scale, the estimated quantity of plastic from Mina disposed of in the landfill in the same year was just under 5 t, which had been generated in only five days.

This huge quantity of plastic should be considered as a problem because not only is plastic not a degradable material (when buried in the landfill), but it is one of the most important recyclable materials. As a result, this research focused on finding a solution for plastic (as a first step in the overall waste solution) in phase two of the fieldwork as will be explained in the next chapter (**Chapter 6**).

However, SWM in Mina is divided into two parts: SWM in Mina's streets and SWM in the Mina camps. Therefore, the new alternative should consider this variation. As Mina's streets are always crowded, pilgrims usually find it very hard to reach the waste bins at the sides of the street. On the other hand, the pilgrims have the space inside their camps (1 m^2 per pilgrim (Ministry of Hajj, 2010)) and the time to implement waste sorting at source. Thus, the exemplar project tested optional plastic sorting at source only in the Mina camps.

CHAPTER 6

RESULTS ON THE EXPERIMENTAL INTERVENTION (EXEMPLAR PROJECT)

6-1 Introduction

The scale of the pilgrimage to Mina exposes Saudi Arabia to world scrutiny and places major stress on its waste management system, which, even without the additional flows, would not be considered environmentally advanced compared to those in the developed world.

The review of the literature and the analysis of the additional waste systems employed during the pilgrimage season (**Chapter 1** and **Chapter 5**) show that, to date, Mina authorities have attempted to improve waste collection and storage only but they have not improved waste management, especially controlling waste generation and disposal. In addition, they have not addressed the need to promote actions higher in the waste hierarchy, such as recycling and reuse. Thus, the importance of implementing an alternative to this system has emerged, as improvements are needed in several aspects, such as gaining benefit from waste and not just burying it in landfill. One of the most successful methods to gain benefit from waste is waste recycling (**Section 2-2-5**). Furthermore, waste sorting at the source of generation is considered as a key prerequisite for the success of any waste recycling system.

Many prestigious events, such as the Olympics and major music festivals, have seen the need to test and demonstrate what can be done through exemplar projects. All such projects focus on the primacy of stimulating recycling or reuse by improving the treatment infrastructure. Projects at such events tend to be comprehensive and depend on strong leadership from the event organisers coupled with an excellent partnership with the local decision makers and waste-service providers. As the waste system in Mina is underdeveloped and the municipal authorities are unprepared at this stage to invest in a comprehensive change to the existing provision, this PhD project had to have a more limited scope.

However, the performance of and the awareness generated by implementation were intended to signpost the way forward for the future. Therefore, the pilgrims' ability to sort out their waste at source was tested by implementing a pilot exemplar project (sorting at source project) (**OBJ4**, **Section 3-2**) based on the methodology detailed in **Section 4-9**.

Implementation of the sorting project was limited to three different camps selected on the basis that they exhibited varying levels in the attributes identified through the literature review as being significant in terms of sorting behaviour (**Section 2-3-4**), specifically, education, living standards, and recycling background and habit (**Figure 4-6**). These selected camps were the Egyptian pilgrims' camp, the Western European and Australian pilgrims' camp, and the Pakistani pilgrims' camp. The pilgrims in these camps were asked to sort only plastic (plastic bottles + other plastic but not plastic films, as explained in **Section 4-9-1** about the required type of plastic to be sorted). This is because plastic: is the most non-biodegradable waste component in the Mina camps, is one of the most important recyclable materials, and has great potential to recover value and be processed into energy or as a secondary raw material (**Sections 2-3-1, 2-3-2, 4-9-1** and **5-7**).

The data for each camp include the number of pilgrims, the compactor box waste composition, the weight of the compactor box as recorded by Makkah Municipality, the quantity of sorted plastic in the uncontaminated sorting bags (SPC) divided into intervals of about three days, supervisors' notes, and the result of the informal interviews with the managers of the three camps.

6-2 Sorting Result for each Camp

6-2-1 Egyptian Pilgrims' Camp

This camp was provisioned for VIP Egyptian pilgrims requiring VIP services, such as refrigerators filled with soda cans, fresh juices (mostly in plastic bottles) and plastic bottles of water **(Figure 6-1)**. **Figure 6-2** shows the composition of waste from the camp compactor box, which reflects the effect of these refrigerators; the obtained percentage of the plastic bottles in the camp compactor box was about 10.1%.

About 1500 pilgrims were accommodated in this camp. They disposed of about 5 t (TWC) of waste in the camp compactor box (Cleaning Department, 2011), where MCW= 4.1 t and XCW= 5 t (as explained in **Section 5-3-2**). This quantity of waste was generated during four out of the five Mina days. There were no pilgrims in this camp during the last day of Mina. This means that the daily disposal rate per pilgrim in this camp compactor box was 0.83 $kg.p^{-1}.d^{-1}$ for XCW and 0.68 $kg.p^{-1}.d^{-1}$ for MCW.

Figure 6-1 Refrigerators filled with drinking bottles in Egyptian camp (A and B), where the green bin is placed beside the refrigerator (part A)

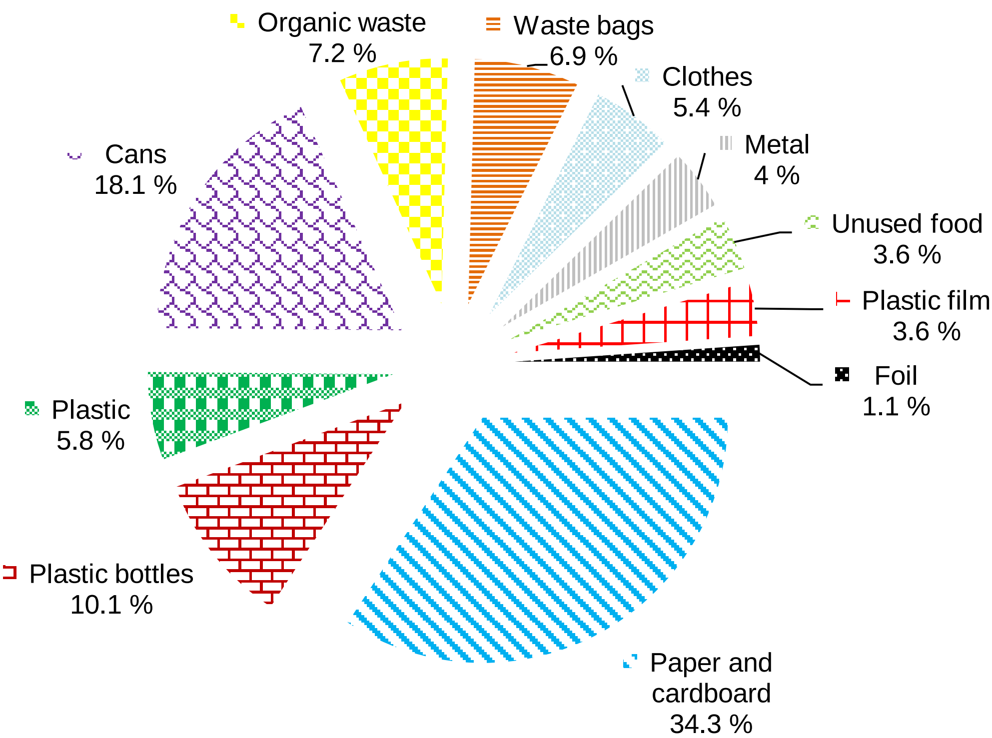

Figure 6-2 Compactor box waste composition in Egyptian camp

Table 6-1 shows the composition of waste from the camp compactor box as well as the estimated quantity of each component (MCW and XCW). The percentage of plastic waste disposed of in the compactor box was 15.9% (plastic bottles + other plastic without plastic film), and it came in third place in the ranking of main waste components in the camp compactor box. However, as the quantity of sorted plastic (SPU) was collected by the researcher and not thrown into the compactor box, the sorted plastic quantity is not included in **Table 6-1,** which means the plastic waste generated by the pilgrims was more than 15.9%.

Table 6-1 Egyptian camp waste composition and quantity estimation

Waste Type	**Sample Weight (kg)**	**Percentage %**	**Estimated total weight for MCW (kg)**	**Estimated total weight for XCW (kg)**
Plastic bottles	14	10.1	414	505
Other plastic	8	5.8	238	289
Total Plastic	**22**	**15.9**	**652**	**794**
Plastic film	5	3.6	148	181
Paper and cardboard	47.5	34.2	1402	1715
Organic waste	10	7.2	295	361
Unused food (new)	5	3.6	148	181
Cans	25	18.1	742	903
Metal	5.5	4.0	164	199
Clothes	7.5	5.4	221	271
Waste bags	9.5	6.9	283	343
Aluminium foil	1.5	1.1	45	54
Total	**138.5**	**100**	**4100**	**5000**

As the number of pilgrims in this camp was relatively small, only 35 green bins (80 litres in volume) were distributed in this camp (**Section 4-9-2**). These sorting bins were emptied five times daily on each of the three days. Based on **Equation 4-6** and the methodology detailed in **Section 4-9-2**, the daily volume provided to the pilgrims to sort their plastic waste (PV) was 14 $m^3.d^{-1}$. This means that the pilgrims had enough volume to sort out about (MSP) 300 kg of plastic daily into the green bins.

The pilgrims in this camp sorted 155 kg (SPU) of plastic into the green bins in three days (**Table 6-2**). This quantity represents the weight of plastic in the uncontaminated bags only, whereas the contaminated bags were thrown into the compactor box as detailed in **Section 4-9-3**.

The total quantity of the generated plastic (TGP) in this camp equalled the quantity of plastic in the compactor box (DPC) in addition to the quantity of sorted plastic (SPU); this means the percentage of generated plastic waste in this camp was about 19% of the total produced waste. Therefore, the total generated waste (TWG) in this camp (all waste in compactor box (TWC) + sorted plastic (SPU)) was 4255 kg for MCW and 5155 kg for XCW (assumed all generated waste was disposed of in the compactor box).

Table 6-2 Daily quantity of sorted plastic in the uncontaminated sorting bags (SPU) by the pilgrims in the Egyptian camp

Date	**Starting Time**	**Ending Time**	**Quantity of Sorted Plastic in the uncontaminated bags (SPU) (kg)**
6/11/2011	12:00	22:00	60
7/11/2011	00:00	22:00	48
8/11/2011	00:00	18:00	47
Total			**155**

The total quantity of plastic generated, TGP (sorted plastic (SPU) + plastic in compactor box (DPC)) by the pilgrims during Mina days (four days) was 807 kg (538 $g.p^{-1}$) for MCW and 949 kg (633 $g.p^{-1}$) for XCW. However, the pilgrims were disposing of plastic for about four days, whereas they were sorting for about three days. Thus, the daily comparison between the sorted and the disposed of plastic should give a better understanding of the sorting percentages than would the overall comparison. The daily plastic generation was 202 $kg.d^{-1}$ (135 $g.p^{-1}.d^{-1}$) for MCW or 237 $kg.d^{-1}$ (158 $g.p^{-1}.d^{-1}$) for XCW (**Table 6-3**).

Based on **Equation 6-1**, the plastic recovery rate varies between 25.6% for MCW and 21.8% for XCW (**Table 6-3**). All of the previous figures were based on the assumption that all the plastic in the compactor box (DPC) was disposed of by the pilgrims, but (in fact) there were a certain number of contaminated bags in the green bins, which had been thrown into the compactor box. These contaminated bags (unknown weight) were counted as well as the uncontaminated bags (known weight), which gave an idea of the estimated weight of contaminated bags. However, the numbers of the contaminated bags were not the same for the three days. On the first day, as the pilgrims were settling in (they had just arrived at the camp), they produced 40% of uncontaminated bags and the remaining 60% were contaminated bags whereas on the second day, the percentage of uncontaminated bags had increased dramatically to 90% (the pilgrims had got used to the project). On the third day, the percentage of uncontaminated bags had decreased to 50%, as the pilgrims were leaving the camp.

$$\text{Plastic recovery rate} = \frac{\text{Weight of sorted plastic}}{\text{Total weight of generated plastic (TGP)}} \times 100 \qquad \textbf{Equation 6-1}$$

The estimated weight of the contaminated bags was 142.4 kg, with an average of 30% of plastic content as noted by the supervisors. This means there was about 43 kg of plastic in the contaminated bags (**Table 6-3**). This quantity of plastic or part of it should be considered as sorted plastic. Thus, two scenarios were developed as follows:

1. The whole quantity of plastic in the contaminated bags was consciously sorted by pilgrims.

2. Part of this quantity was consciously sorted out, whereas the rest was consciously disposed of as waste (more realistic scenario). The sorted part (SPC) was calculated by subtracting the percentage of disposed plastic in the compactor box from the percentage of plastic in the contaminated bags.

Table 6-3 The daily quantities of total plastic generated and sorted as well as the percentages of plastic recovery in the Egyptian camp

	Day one	**Day two**	**Day three**	**Total**
Daily quantity of generated plastic/MCW (kg)	202	202	202	606
Daily quantity of generated plastic/XCW (kg)	237	237	237	712
Daily quantity of generated plastic per pilgrim/MCW ($g.p^{-1}.d^{-1}$)	135	135	135	404
Daily quantity of generated plastic per pilgrim/XCW ($g.p^{-1}.d^{-1}$)	158	158	158	475
Daily quantity of sorted plastic in the uncontaminated bags per pilgrim ($g.p^{-1}.d^{-1}$)	40	32	31	103
Daily quantity of sorted plastic in the uncontaminated bags (kg)	60	48	47	155
Daily quantity of sorted plastic in the contaminated bags (kg) / first scenario	27	2	14	43
Total quantity of sorted plastic (uncontaminated (SPU) + contaminated bags (SPC)) / first scenario (kg)	87	50	61	198
Daily quantity of sorted plastic in the contaminated bags (kg)/ second scenario	12	1	7	20
Total quantity of sorted plastic (uncontaminated (SPU)+ contaminated bags(SPC)) / second scenario (kg)	72	49	54	175
Plastic recovery rate based on Equation 6-1	**Day one**	**Day two**	**Day three**	**Avg.**
From the uncontaminated bags / MCW (%)	29.7	23.8	23.3	25.6
From the uncontaminated bags / XCW (%)	25.3	20.2	19.8	21.8
Based on first scenario/ MCW (%)	43.1	24.8	30.2	32.7
Based on first scenario/ XCW (%)	36.7	21.1	25.7	27.8
Based on second scenario/ MCW (%)	35.6	24.1	26.6	**29**
Based on second scenario/ XCW (%)	30.6	20.5	22.6	**25**

In the first scenario, the total weight of sorted plastic in the contaminated bags (SPC) was 43 kg, which represents the entire quantity of plastic in the contaminated bags. However, in the second scenario, the percentage of sorted plastic in the contaminated bags was calculated as follows:

The percentage of plastic in the compactor box = 15.9%

The noted percentage of plastic in the contaminated bags = 30%

The percentage of sorted plastic in the contaminated bags based on the second scenario = 30 –15.9 = 14.1%

The total quantity of sorted plastic in the contaminated bags (SPC) = 14.1% × 142.4 = 20 kg

The results of the plastic recovery percentages for the both scenarios as well as the daily quantity of sorted plastic in the contaminated bags are shown in **Table 6-3**. From **Table 6-3,** it can be concluded that the pilgrims' actual plastic sorting behaviour in this camp varied between 25% and 29% (average 27%) based on the results from the second scenario, which provides the more realistic sorting percentages.

6-2-2 Western Europe and Australian Pilgrims' Camp

The same procedure that was followed in the Egyptian pilgrims' camp was followed in this camp, but the number of distributed sorting bins was increased to 50 as the number of pilgrims in this camp was higher (4900 pilgrims). Thus, the daily provided volume for the pilgrims to sort out their waste (PV) was 20 m^3. This means that the pilgrims in this camp had sufficient daily volume to sort about 420 kg (MSP) of plastic in the green bins.

Although the pilgrims in this camp came from Western Europe and Australia (where people have to sort their household waste), most of them were originally from India, Pakistan, and Eastern Europe (as observed and reported by the camp manager, **Section 6-4-2**). Also, it was observed by the supervisors (**Section 6-4-1**) and reported by the camp manager **(Section 6-4-2**) that about 70% of the pilgrims were poorly or not highly educated, and most of them did not care about sorting their waste whereas the remainder were highly educated (most of them had postgraduate degrees). These highly educated pilgrims were accommodated in the far western end of the camp (about 30% of the camp area). In this area the greatest quantity of sorted plastic was produced, which indicates that actual behaviour can be affected by level of education. Therefore, in this camp a limited number of pilgrims were very helpful in the sorting project whereas the rest of the pilgrims caused a drop in the quantity of sorted plastic.

The pilgrims in this camp disposed of 7 t (TWC) of waste in the compactor box during five days (Cleaning Department, 2011), where MCW= 6.1 t and XCW= 7 t (as explained in **Section 5-3-2**). The difference between the period of waste generation (five days) and waste sorting (three days) should be considered. Therefore, the total quantity of produced plastic was divided by five in order to estimate the quantity of daily plastic generation. On average, the daily waste disposal rate per pilgrim in this camp compactor box was 0.3 $kg.p^{-1}.d^{-1}$ for XCW and 0.26 $kg.p^{-1}.d^{-1}$ for MCW.

Camp staff did not provide food or drinks (juices and water in plastic bottles) for the pilgrims, but the pilgrims were allowed to cook in the kitchen. As a result, the percentage of plastic waste out of the total waste in this camp compactor box was 10.9%. **Figure 6-3** illustrates the composition of the waste disposed of in this camp compactor box whereas **Table 6-4** shows the estimated weight of each component for MCW and XCW.

Although the pilgrims in this camp disposed of a relatively low quantity of plastic in the compactor box (MCW=665 kg, XCW=778 kg), they sorted out 100 kg (SPU) of plastic (**Table 6-5**) into the green bins over the three days. This quantity of sorted plastic represents the weight of plastic in the uncontaminated bags only, whereas the contaminated bags were thrown into the compactor box as detailed in **Section 4-9-3**. Overall, pilgrims produced 878 kg (XCW) and 765 kg (MCW) of plastic in this camp (sorted into the green bins (SPU) + disposed of in the compactor box (DPC)). However, as mentioned previously, the comparison between the daily quantities is more realistic than the comparison using overall quantities.

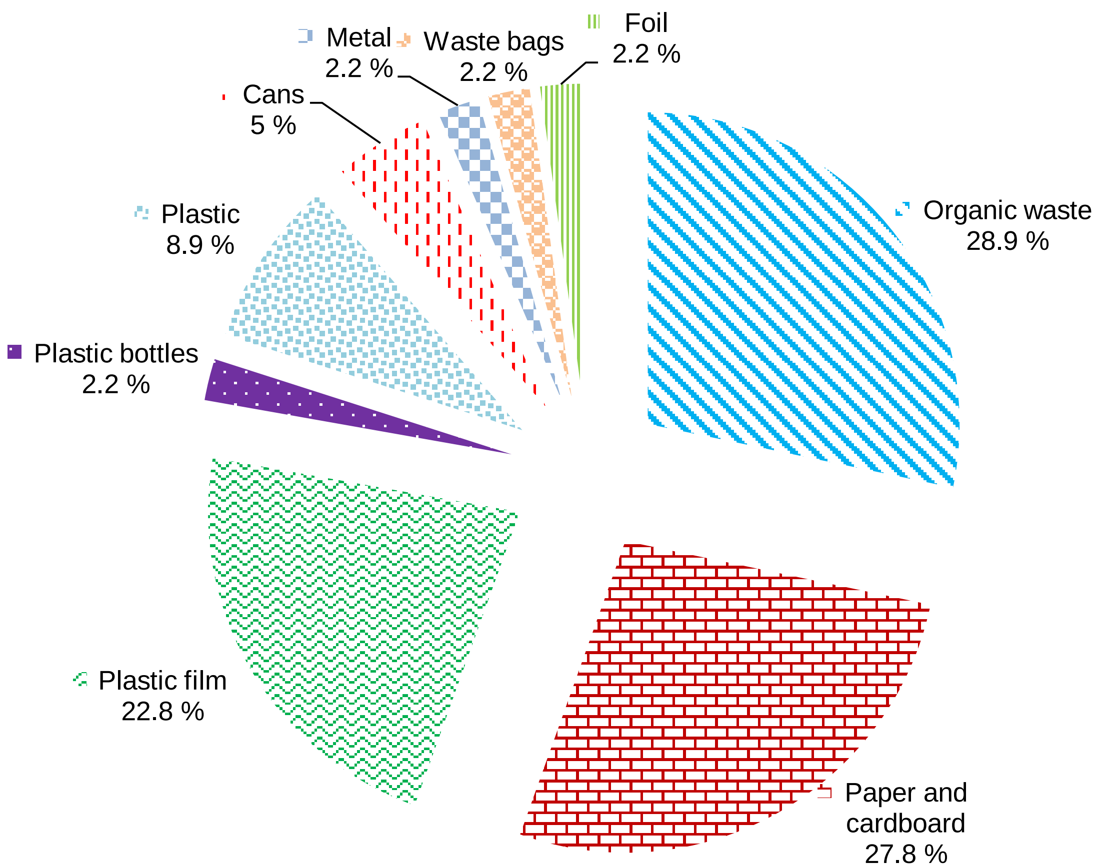

Figure 6-3 Compactor box waste composition in the Western European and Australian pilgrims' camp

Table 6-4 Western European and Australian pilgrims' camp waste components and quantity estimation

Waste Type	Sample Weight (kg)	Percentage %	Estimated total weight for MCW (kg)	Estimated total weight for XCW (kg)
Plastic Bottles	1.0	2.2	134	156
Plastic	4.0	8.7	531	622
Total Plastic	**5**	**10.9**	**665**	**778**
Paper and cardboard	12.5	27.1	1653	1944
Organic Waste	13.0	28.1	1714	2022
Cans	2.3	5.0	305	350
Metal	1.0	2.2	134	156
Waste bags	1.0	2.2	134	156
Plastic film	10.3	22.3	1360	1594
Aluminium Foil	1.0	2.2	134	156
Total	**46.1**	**100**	**6100**	**7000**

Table 6-5 Quantity of sorted plastic in the uncontaminated sorting bags (SPU) by the pilgrims in the Western European and Australian pilgrims' camp

Date	Starting Time	Ending Time	Quantity of Sorted Plastic in the uncontaminated bags (SPU) (kg)
6/11/2011	12:00	22:00	40
7/11/2011	00:00	22:00	33.5
8/11/2011	00:00	18:00	26.5
Total			**100**

As shown in **Table 6-6**, the amount of plastic generated daily in this camp was 153 kg for MCW and 176 kg for XCW (assuming the pilgrims generated the same quantity of plastic every day), whereas the total sorted plastic in the uncontaminated bags (SPU) was 100 kg. However, based on the supervisors' observations, the pilgrims in this camp produced the same percentage of uncontaminated bags at 25% (100 kg) for the three days, whereas 75% of the sorting bags were contaminated and contained an average of 20% plastic. This means the estimated weight of the contaminated bags was 300 kg and the weight of plastic that was thrown into the compactor box was 60 kg. Therefore, the daily quantity of sorted plastic in the contaminated bags was estimated for the two scenarios as follows:

The first scenario: the total weight of sorted plastic in the contaminated bags (SPC) was 60 kg (**Table 6-6**), which represents the whole quantity of plastic in the contaminated bags.

The second scenario: the percentage of plastic in the compactor box = 10.9%

The observed percentage of plastic in the contaminated bags = 20%

The percentage of sorted plastic in the contaminated bags based on the second scenario = 20 –10.9 = 9.1%

The total quantity of sorted plastic in the contaminated bags (SPC) = 9.1% $\times$300 =20 kg

Table 6-6 The daily plastic quantities of total generated, sorted as well as the percentages of plastic recovery in Western European and Australian pilgrims' camp

	Day one	**Day two**	**Day three**	**Total**
Daily quantity of generated plastic/MCW (kg)	153	153	153	459
Daily quantity of generated plastic/XCW (kg)	176	176	176	528
Daily quantity of generated plastic per pilgrim/MCW ($g.p^{-1}.d^{-1}$)	31	31	31	94
Daily quantity of generated plastic per pilgrim/XCW ($g.p^{-1}.d^{-1}$)	36	36	36	108
Daily quantity of sorted plastic in the uncontaminated bags per pilgrim ($g.p^{-1}.d^{-1}$)	8	7	5	20
Daily quantity of sorted plastic in the uncontaminated bags (kg)	40	33.5	26.5	100
Daily quantity of sorted plastic in the contaminated bags (kg) / first scenario	24	20	16	60
Total quantity of sorted plastic (uncontaminated (SPU) + contaminated bags (SPC)) / first scenario (kg)	64	53.5	42.5	160
Daily quantity of sorted plastic in the contaminated bags (kg)/ second scenario	11	9	7	27
Total quantity of sorted plastic (uncontaminated (SPU)+ contaminated bags (SPC)) / second scenario (kg)	51	42	34	127
Plastic recovery rate based on Equation 6-1	**Day one**	**Day two**	**Day three**	**Avg.**
From the uncontaminated bags / MCW (%)	26.1	21.9	17.3	21.8
From the uncontaminated bags / XCW (%)	22.8	19.1	15.1	19.0
Based on first scenario/ MCW (%)	41.8	35.0	27.8	34.9
Based on first scenario/ XCW (%)	36.4	30.4	24.1	30.3
Based on second scenario/ MCW (%)	33.3	27.8	22.0	**27.7**
Based on second scenario/ XCW (%)	29.0	24.3	19.2	**24.2**

The results of the plastic recovery percentages (based on **Equation 6-1**) for both scenarios as well as the daily quantities of generated plastic and of sorted plastic in the uncontaminated bags, and the results of the both scenarios (sorted plastic in the contaminated bags) are shown in **Table 6-6**. From **Table 6-3,** it can be concluded that the pilgrims' actual plastic sorting behaviour in this camp varied between 24.2% and 27.7% (average 25.6%) based on the results of the second scenario, which offers the most realistic sorting percentages.

6-2-3 Pakistani Pilgrims' Camp

Again in this camp, the same procedure of waste sorting as in the previous camps was followed, but all contaminated blue bags and uncontaminated bags (from the green bins) were stored and not disposed of in the compactor box (**Table 6-7**), as there was a big storage area. Thus, the total weight of the waste generated (TGW) in this camp was equal to the weight of the waste in the compactor box (TWC), which was 4 t (MCW = 3.1 t and XCW = 4 t) collected over four days (Cleaning Department, 2011), in addition to the weight of the contaminated bags (340.3 kg) and the weight of the uncontaminated bags (36 kg), which were collected over three days. Therefore, the total weight of plastic generated in this camp was as follows:

1- weight of sorted plastic (SPU) = 36 kg.
2- weight of plastic in the contaminated bags (SPC). As observed, the percentage of plastic in the contaminated bags was 15%, which means there was 51 kg of plastic in the contaminated bags (**Table 6-7**).
3- weight of plastic in the compactor box (DPC) (**Table 6-8**). **Figure 6-4** shows the compactor box waste composition in this camp.

Therefore, the total plastic waste generated (TGP) by the Pakistani camp over four days was 316 kg (113 $g.p^{-1}$) for MCW and 382 kg (136 $g.p^{-1}$) for XCW.

Table 6-7 Quantity of plastic in the uncontaminated and contaminated sorting bags

Date	**Starting time**	**Ending time**	**Quantity of sorted plastic in the uncontaminated bags (SPU) (kg)**	**The weight of contaminated bags (kg)**	**Estimated plastic quantity in the contaminated bags (SPC) (kg)**
6/11/2011	12:00	22:30	10	63	9.5
7/11/2011	00:00	22:00	15	111.3	16.7
8/11/2011	00:00	18:00	11	166	24.9
Total			**36**	**340.3**	**51**

Table 6-8 Pakistani camp waste quantity estimation

Waste Type	**Sample Weight (kg)**	**Percentage %**	**Estimated total weight for MCW (kg)**	**Estimated total weight for XCW (kg))**
Plastic bottles	3	3.4	105	136
Plastic	3.5	4.0	124	159
Total Plastic	6.5	7.4	229	295
Paper and cardboard	26.5	30.0	930	1201
Organic waste	20.75	23.5	729	941
Unused food (new)	25	28.3	877	1133
Cans	1.25	1.4	43	57
Waste bags	3	3.4	105	136
Plastic film	4.25	4.8	149	193
Foil	1	1.1	37	45
Total	**88.25**	**100**	**3100**	**4000**

In this camp, there were about 2800 pilgrims; therefore, 40 sorting green bins were distributed with a daily provided volume (PV) of 16 m^3, where MSP = 330 kg. Based on the sorting bags collected from the green bins, it was found that the pilgrims in this camp produced very low percentages of uncontaminated bags in comparison with contaminated ones, starting at 13.7% on the first day with this percentage decreasing to 11.9% and 6.2% on the second and third day respectively. This seems to confirm the effect of not understanding the difference between plastic and other waste components as was observed by the supervisors.

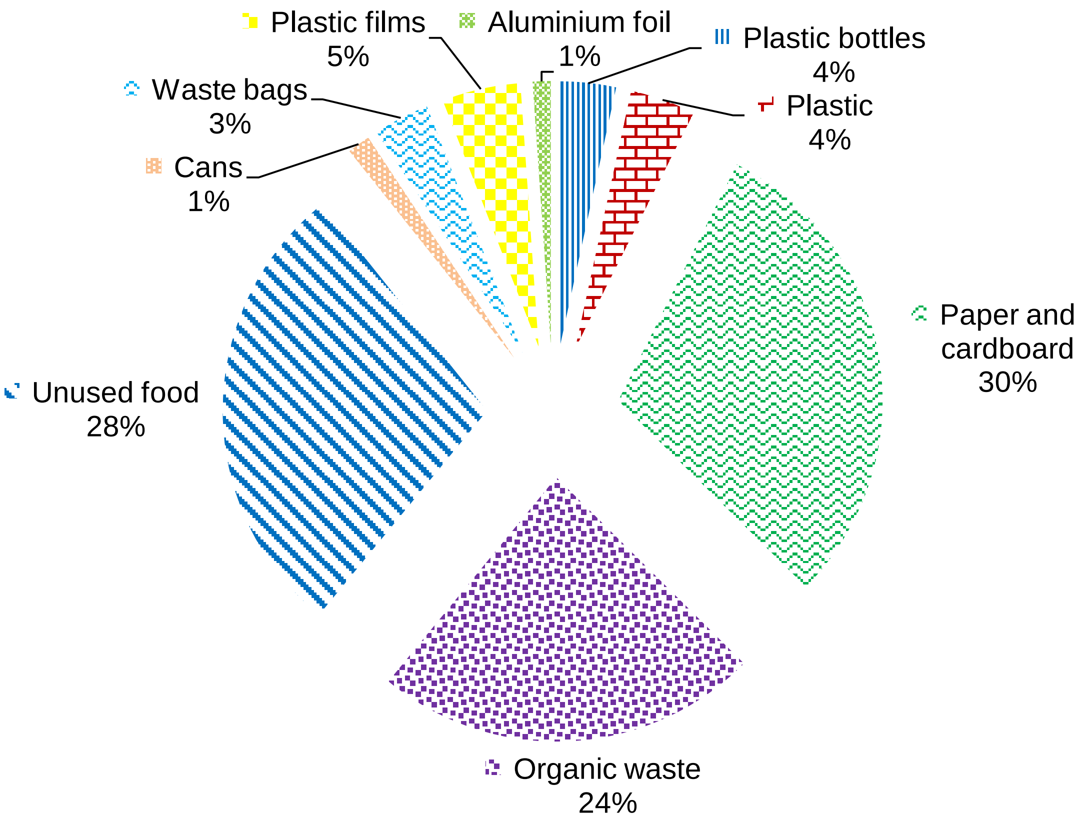

Figure 6-4 Compactor box waste composition in Pakistani camp

It was observed that the pilgrims tried to sort out their plastic waste, but the problem was that many of them could not identify plastic from other waste components like aluminium cans and foil plates, cork, and some types of paper and cardboard (**Figure 6-5**). In addition, many of them were illiterate (as reported by the manager and the supervisors), which means they could not read the posters or the brochures.

Figure 6-5 Examples show that some of the Pakistani pilgrims did not differentiate between plastic and other types of waste, such as aluminium foil plates (part B and C) and cans (part A) based on the on-site observations

Figure 6-6 Part of the unused food boxes found in the Pakistani camp compactor box. Some of the pilgrims said they threw away the food boxes, as they wanted cooked meals ('real food')

Another problem observed in this camp, (during the process of compactor box sampling) was the high number of unused snacks (in their original packaging). The camp manager said the pilgrims did not like the food provided to them by the charity organization because it was a snack and not a real food "as the pilgrims said". Therefore, a huge quantity of snack food was disposed of in the compactor box as the pilgrims bought their food from food shops (**Figure 6-6**).

Quantity of sorted plastic in the contaminated bags (SPC) according to the first scenario

Total measured weight of the clean plastic bags (SPU) = 36 kg (9.6%)

Total measured weight of the contaminated bags = 340.3 kg (90.4%)

The estimated (observed) percentage of plastic in the contaminated bags = 15%

The estimated quantity of sorted plastic in the contaminated bags (SPC)

$= 15\% \times 340.3 = 51$ kg

Quantity of sorted plastic in the contaminated bags (SPC) according to the first scenario

The percentage of plastic in the compactor box = 7.4%

The estimated (observed) percentage of plastic in the contaminated bags = 15%

The percentage of sorted plastic in the contaminated bags = 15 – 7.4 = 7.6%

The estimated quantity of sorted plastic in the contaminated bags (SPC) = $7.6\% \times 340.3$ = 26 kg

Similarly to the previous camps, **Table 6-9** summarizes the daily quantities of sorted and generated plastic. Based on **Table 6-9,** it can be concluded that the pilgrims' actual plastic sorting behaviour in this camp varied between 21.6% and 26.1% (average 24%)

based on the second scenario, which is the most representative of the sorting percentages.

Table 6-9 The daily quantities of total plastic generated and sorted as well as the percentages of plastic recovery in the Pakistani camp

	Day one	Day two	Day three	Total
Daily quantity of generated plastic/MCW (kg)	79	79	79	237
Daily quantity of generated plastic/XCW (kg)	96	96	96	288
Daily quantity of generated plastic per pilgrim/MCW ($g.p^{-1}.d^{-1}$)	28	28	28	85
Daily quantity of generated plastic per pilgrim/XCW ($g.p^{-1}.d^{-1}$)	34	34	34	103
Daily quantity of sorted plastic in the uncontaminated bags per pilgrim ($g.p^{-1}.d^{-1}$)	4	5	4	13
Daily quantity of sorted plastic in the uncontaminated bags (kg)	10	15	11	36
Daily quantity of sorted plastic in the contaminated bags (kg) / first scenario	9	17	25	51
Total quantity of sorted plastic (uncontaminated (SPU) + contaminated bags (SPC)) / first scenario (kg)	19	32	36	87
Daily quantity of sorted plastic in the contaminated bags (kg)/ second scenario	5	8	13	26
Total quantity of sorted plastic (uncontaminated (SPU)+ contaminated bags(SPC)) / second scenario (kg)	15	23	24	62
Plastic recovery rate based on Equation 6-1	**Day one**	**Day two**	**Day three**	**Avg.**
From the uncontaminated bags / MCW (%)	12.7	19.0	13.9	15.2
From the uncontaminated bags / XCW (%)	10.5	15.7	11.5	12.6
Based on first scenario/ MCW (%)	24.1	40.5	45.6	36.7
Based on first scenario/ XCW (%)	19.8	33.3	37.5	30.2
Based on second scenario/ MCW (%)	18.7	29.7	29.9	26.1
Based on second scenario/ XCW (%)	15.5	24.6	24.7	21.6

6-2-4 A Comparative Summary of the Results from the Three Camps

Figure 6-7 summarises, for each of the three camps, the total quantities of total sorted plastic in uncontaminated bags (SPU) per pilgrim over the three days, the total sorted plastic according to the second scenario (TSPS) per pilgrim (three days), and the total generated plastic (TGP) per pilgrim over three days only for MCW and XCW (based on Tables **6-3**, **6-6** and **6-9**). However, the supervisors observed that not all the pilgrims participated in the sorting project, so it was assumed in **Section 4-10** that all the pilgrims who participated in sorting project sorted all the plastic they generated, and the remaining pilgrims did not participate at all. Therefore, it was better to compare the overall quantities of sorted plastic rather than the quantity of sorted plastic per pilgrim, as not all the pilgrims participated in the sorting project.

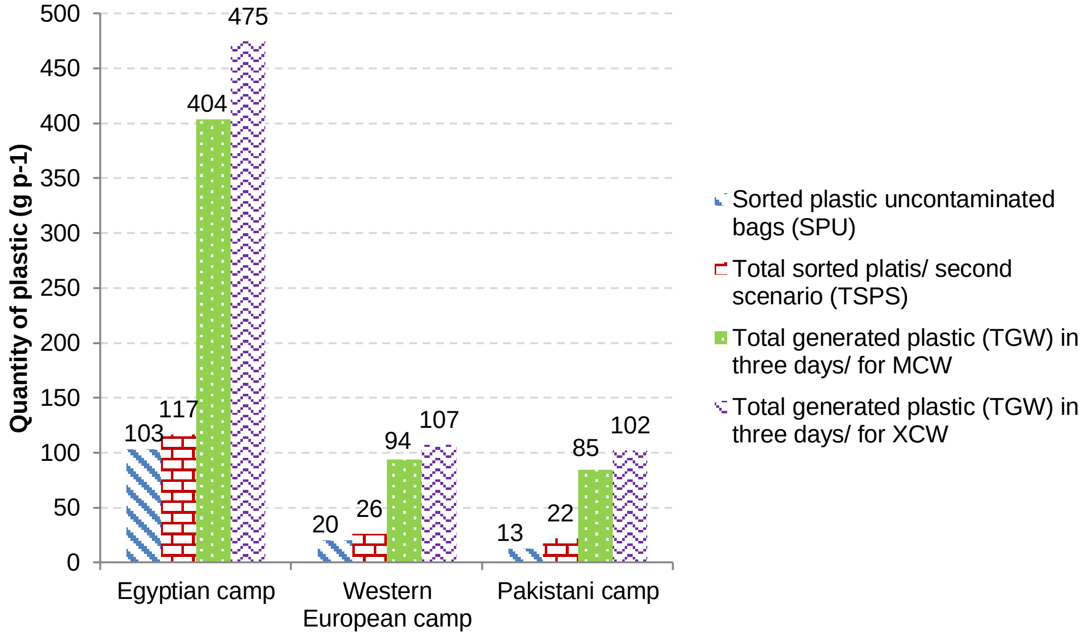

Figure 6-7 The quantity of sorted plastic and the quantity of disposed of plastic per pilgrim (gp^{-1}) in each camp

Figure 6-8 shows (for the three camps) the total sorted plastic in the uncontaminated sorting bags (SPU) and the total sorted plastic based on the second scenario (TSPS) where the quantity of sorted plastic in the contaminated sorting bags was added to SPU. The comparison between SPU and TSPS can be done by calculating the percentage of change between them according to **Equation 6-2** as shown in **Figure 6-9**. The percentages showed in **Figure 6-9** represent the differences between the actual results of sorting in the uncontaminated sorting bags and the total of consciously sorted plastic in all the sorting bags.

$$\text{The percentage of change} = \frac{\text{TSPS} - \text{SPU}}{\text{SPU}} \times 100 \qquad \textbf{Equation 6-2}$$

Where: TSPS = Total sorted plastic according to the second scenario

SPU = Sorted plastic in the uncontaminated bags

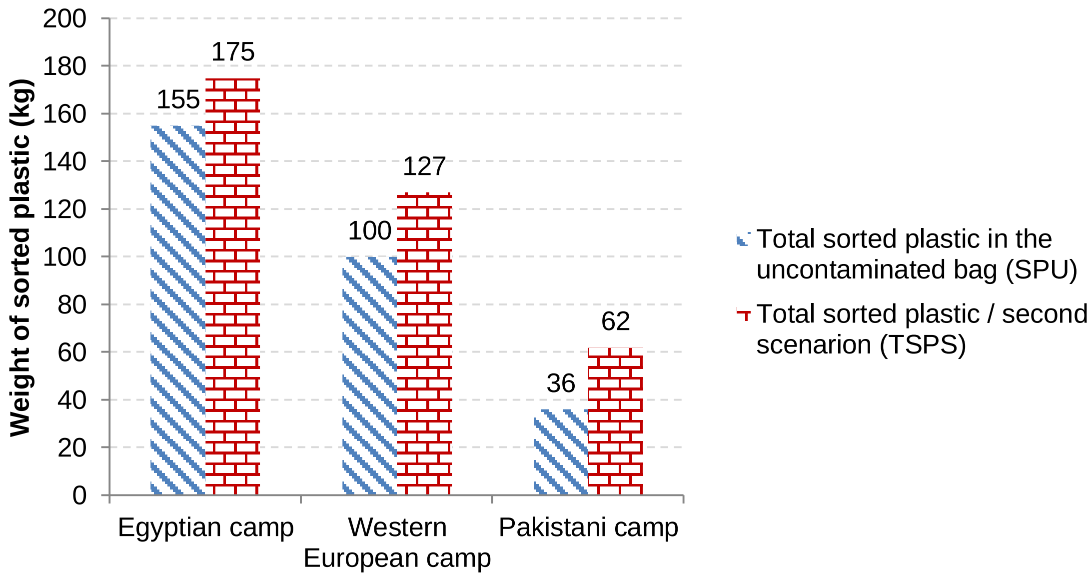

Figure 6-8 The total sorted plastic in the uncontaminated sorting bags (SPU) and the total sorted plastic based on the second scenario (TSPS) mention in **Section 6-2-1**

From **Figure 6-9,** it can be seen that the lowest percentage of change was for the Egyptian camp then the Western European and Australian pilgrims' camp and, finally, the Pakistani camp. This means that the pilgrims in the Egyptian camp produced the lowest percentage of sorted plastic in the contaminated sorting bags in comparison with the uncontaminated ones, whereas the Pakistani pilgrims produced the greatest percentage of sorted plastic in the contaminated sorting bags.

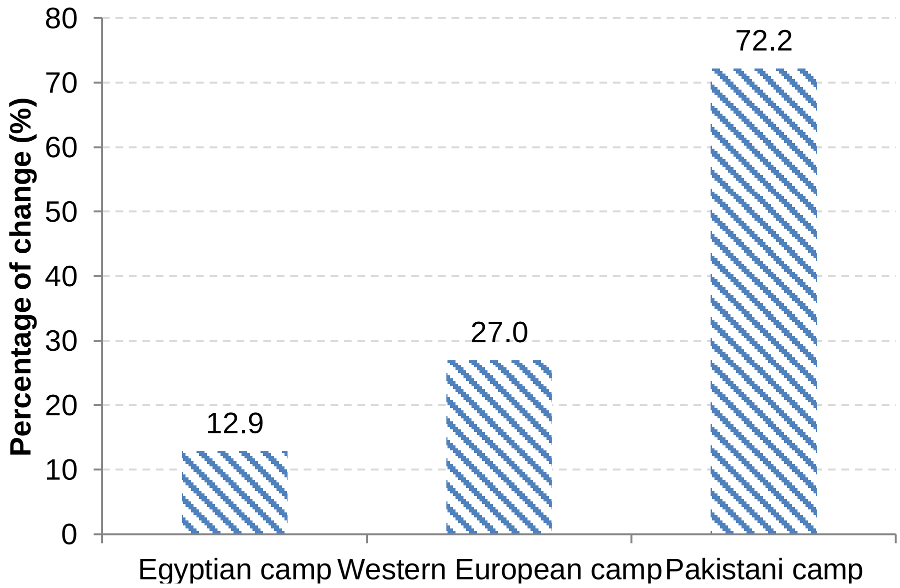

Figure 6-9 The percentages of change between sorted plastic in the uncontaminated bags (SPU) and total sorted plastic according to the second scenario (TSPS) based on **Equation 6-2**, which shows the difference between the uncontaminated quantity of sorted plastic and the total quantity of sorted plastic in all sorting bags

The average percentages of sorted plastic should be calculated to estimate the percentages of participants in the sorting project based on the two assumptions in **Section 4-10**. **Table 6-10** summarises the exemplar project's daily results for the three camps as well as the overall average percentages. In addition, **Figure 6-10** shows a comparison between the average daily percentages of plastic recovery from the uncontaminated bags and the average daily percentages of plastic recovery based on the second scenario for both MCW and XCW.

The overall daily average of sorted plastic in the uncontaminated bags (SPU) was about 19%; however, this percentage does not represent the pilgrims' actual sorting behaviour, which can be better represented by the overall daily average of sorted plastic based on the second scenario (TSPS). Based on the average results of the second scenario (TSPS) (the most realistic), it was found that 24% to 27% (mean of 25.5%) of the pilgrims in each camp participated in the sorting project. The differences between the results for the three camps are not practical.

As the total percentage of sorted plastic is known, the percentage of participants in the sorting project in each camp is the same, and as it was assumed in **Section 4-10** that all the pilgrims who participated in the exemplar project sorted all of their plastic waste and that all the pilgrims generated same quantity of plastic, thus, it is concluded that the overall pilgrims' actual sorting behaviour can be predicted to be around 25.5%. This means, based on the two assumptions in **Section 4-10**, about 25% of the pilgrims participated in the sorting project. In other words, if the sorting project were to be generalised over all the Mina camps (with the same circumstances), it is expected that about 25% of pilgrims would participate in this project.

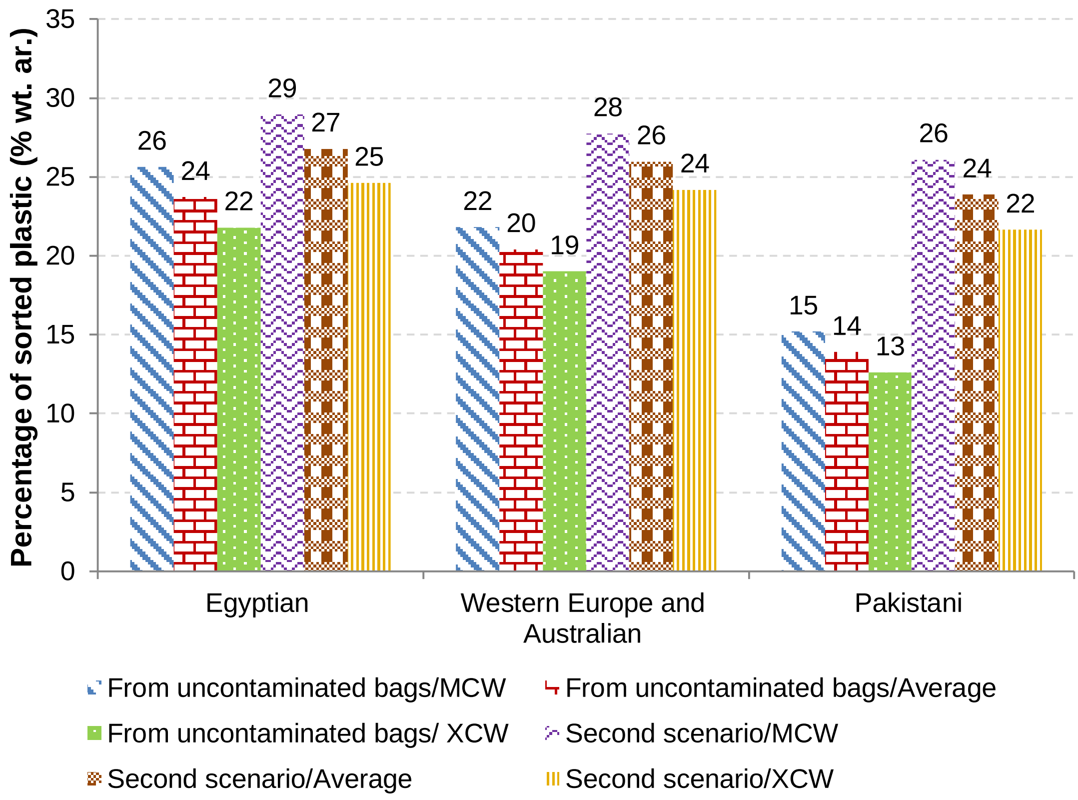

Figure 6-10 A comparison between the daily percentages of sorted plastic in each camp based on the uncontaminated sorted plastic bags and proportion of plastic in the contaminated bags (second scenario – **Section 6-2-1**)

Table 6-10 Summary of the sorting project: total quantities of generated and sorted plastic, and the daily results and their averages in the three camps

Camp	**Egyptian**			**Western Europe and Australian**			**Pakistani**			**Average**
Number of pilgrims in the camp	1500			4900			2800			
Number of days which pilgrims occupied the camp	4			5			4			
The daily weight of sorted plastic in the uncontaminated bags (kg)	60	48	47	40	33.5	26.5	10	15	11	
Total weight of sorted plastic in the uncontaminated bags (kg)	155			100			36			
The daily weight of sorted plastic based on the second scenario in **Section 6-2-1** (kg)	72	49	54	51	42	34	14.8	23.5	23.6	
Total weight of sorted plastic based on the second scenario in **Section 6-2-1** (kg)	175			127			61.9			
The daily weight of generated plastic/ MCW (kg)	202			153			79			
The daily weight of generated plastic/ XCW (kg)	237			176			95.5			
Total weight of generated plastic/ MCW (kg)	807			765			316.4			
Total weight of generated plastic/ XCW (kg)	949			878			381.6			
The daily plastic recovery										
The average daily plastic recovery from uncontaminated bags/ MCW (%)	25.6			21.8			15.2			20.9
The average daily plastic recovery from uncontaminated bags/ XCW (%)	21.8			19			12.6			17.8
The average daily plastic recovery from uncontaminated bags/ average (%)	23.7			20.4			13.9			**19.3**
The average daily plastic recovery based on the second scenario in **Section 6-2-1** / MCW (%)	29			27.7			26.1			27.6
The average daily plastic recovery based on the second scenario in **Section 6-2-1** / XCW (%)	25			24.2			21.6			23.6
The average daily plastic recovery based on the second scenario in **Section 6-2-1** / average (%)	27			26			23.9			**25.5**

6-3 Predictive Accuracy of Pilgrims' Stated Intention

As mentioned in **Section 4-10**, the level of predictive accuracy of pilgrims' recycling stated intention (PASI) can be estimated by comparing the predicted future behaviour (based on stated intention, **Table 5-37**) with the actual behaviour from **Table 6-10**. However, the presence of a recycling habit plays an important role in this comparison, as habit is significantly related to intention. Thus, the predictive accuracy of the pilgrims' stated sorting intention is calculated twice (**Table 6-11**): if all the pilgrims have the habit to recycle (first habit scenario) or if none of the pilgrims has the recycling habit (second habit scenario). Then, the results were normalised based on the pilgrims' reported habit in the pilgrims' questionnaire as detailed in **Section 4-10.**

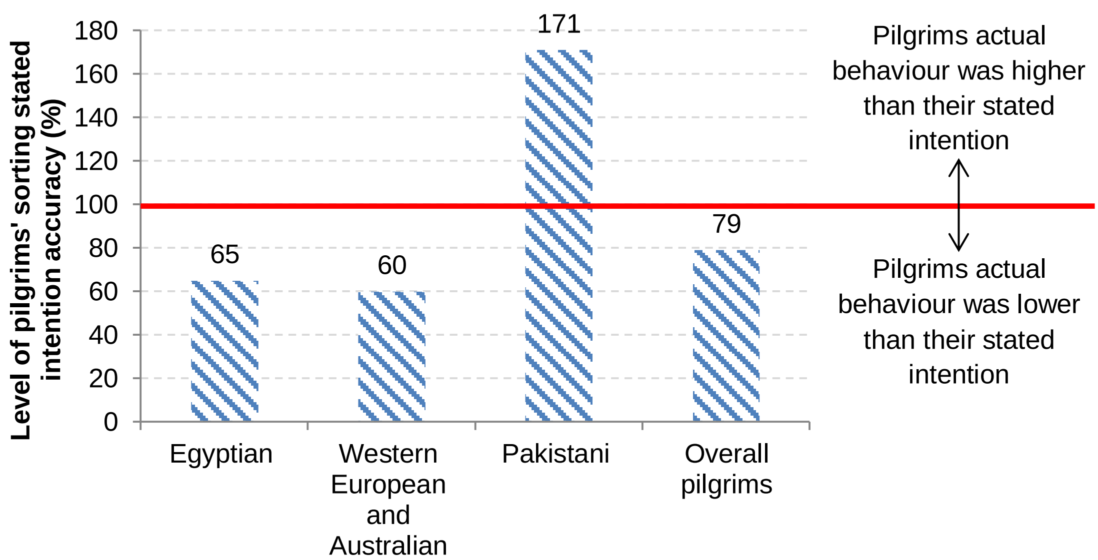

Figure 6-11 Predictive accuracy of pilgrims' stated intention (PASI) for the three nationalities groups and the overall pilgrims

Overall, the predictive accuracy of the pilgrims' stated intention was about 79% (**Figure 6-11**). This is one of the main key results in this research, where it was found that stated intention can predict future behaviour if the two habit scenarios (**Section 4-10**) derived from (Fujii and Gärling, 2003) were used to adjust the stated intention as detailed in **Section 4-10.** In **Figure 6-11**, if the percentage of predictive accuracy of the stated intention (PASI) is below 100%, this means the pilgrims' actual behaviour was less than their stated intention, whereas if PASI is above 100%, it means that the actual behaviour was greater than the stated intention.

Table 6-11 The predictive accuracy of pilgrims' stated sorting intention (PASI) calculated based on the detailed methodology in **Section 4-10**

Camp	**Egyptian**	**Western European and Australian**	**Pakistani**	**Overall pilgrims**
Percentage of pilgrims who have recycling habit, based on the responses to the questionnaire (%)	36.8	86	29.3	45
Percentage of pilgrims who do not have recycling habit, based on the responses to the questionnaire (%)	63.2	14	70.7	55
Percentage of pilgrims expected to perform sorting at their camps (first habit scenario: all pilgrims have recycling habit), (**Table 5-37**)	50.4	45.8	17.2	38.2
Percentage of pilgrims expected to perform sorting at their camps (second habit scenario: all pilgrims do not have recycling habit), (**Table 5-37**)	37.9	34.5	13.0	28.7
The average daily plastic recovery based on the second scenario / average (%), (**Table 6-10**)	27	26	23.9	**25.5**
Predictive accuracy of pilgrims' stated intention (PASI) if all pilgrims have recycling habit (first habit scenario, **Section 4-10**) (%)	53.6 =(27/50.4) ×100	56.8	139.0	66.8
Predictive accuracy of pilgrims' stated intention (PASI) if all pilgrims do not have recycling habit (second habit scenario, **Section 4-10**) (%)	71.2 =(27/37.9) ×100	75.4	183.8	88.9
The average predictive accuracy of pilgrims' stated intention based on the existence of recycling habit (%)	**65** =(53.6×36.8/100) + (71.2×63.2/100)	**60**	**171**	**79**

6-4 Factors Affecting pilgrims' Actual Sorting Behaviour

All the recorded factors that affected the pilgrims' sorting actual behaviour were derived from the supervisors' on-site observations and the interviews with the camp managers. However, the researcher's on-site observation was not included here to avoid bias and subjective opinion.

6-4-1 Based on Supervisors' Notes

Some of the supervisors' notes and feedback have been used previously to estimate some of the missing data, such as the weight of the contaminated sorting bags and the percentage of plastic in them. However, the rest of the supervisors' notes were used to identify the factors that affected the pilgrims' sorting behaviour. As mentioned in **Section 4-9-3**, the supervisors' notes were based on their observations and discussions with the pilgrims; therefore, they were able to record many of the factors that affected the pilgrims' sorting behaviour. These factors are summarized with their variable values in **Table 6-12**. To avoid erroneous judgments, the supervisors were not asked to give their opinion about how each factor affected the pilgrims' behaviour (positively or negatively), but they were asked to give a degree of the presence of each factor. Further research needs to approach these factors in terms of the value of the impact and its sign (negative or positive).

Another important factor not included in **Table 6-12** is food catering and its relation to the pilgrims' sorting behaviour. All the supervisors were asked to monitor the pilgrims while they were eating to detect the relationship between eating and plastic waste generation. The supervisors in the Egyptian camp noted that the method of food catering in this camp (buffet) resulted in a greater quantity of plastic being produced, because the pilgrims used plastic plates and consumed large amounts of juice and water in plastic bottles. In the Western European and Australian pilgrims’ camp, the pilgrims consumed a lot of plastic milk bottles and plastic plates. However, in the Pakistani camp, the pilgrims bought most of their food in aluminium foil plates (**Figure 6-5**).

Table 6-12 Factors that affected the pilgrims' sorting behaviour and their variable values in the three camps based on supervisors' notes

Factor	**Camp**		
	Egyptian	**Western European & Australian**	**Pakistani**
Pilgrims’ sorting background	Medium	High	Low
Pilgrims’ level of education	High	Medium	Low
Pilgrims’ social level	Upper medium	Medium	Low
Pilgrims interest in the project	Medium	Medium	Medium
Emptying camp waste bins when they are full	High	Low	Medium
Camp cleaning workers’ professionalism	High	Low	Medium
Capacity of camp waste bins	High	Low	Medium
Quantity of generated plastic	High	Medium	Low
Level of disturbance during pilgrims’ arrival and departure	High	Medium	Medium
Time to educate pilgrims about the project before the event	Medium	Medium	Medium
Existence of free plastic bottled drinks in refrigerators	Yes	No	No
Pilgrims ability to identify plastic	Yes	Yes	No
Perceived difficulty in communication (spoken languages)	No	Yes	Yes

Based on the supervisors' notes and feedbacks, the main factors that affected this project were

- the pilgrims interest in the sorting project
- the pilgrims’ level of education
- the method of food catering inside the camp
- the existence of the free drinks refrigerator.

6-4-2 Based on Managers' Interviews

Table 6-13 The results of the interviews with the three camp managers', which show the number of pilgrims in each camp, pilgrims' social and educational levels, and other background and feedback information

Question	Camp		
	Egyptian	**Western European and Australian**	**Pakistani**
Pilgrims nationality	Egyptian	Most of them originally Pakistanis, Indians and Eastern Europeans, but all of them came from Western European and Australian countries	Pakistani
Number of pilgrims	1500	4900	2800
Provide food service	Yes	No, (but I provided kitchen for cooking)	No (charity organization provided snacks)
Compactor box assessment	Good idea but it needs to be underground and bigger	I do not like odour and leachate resulting from it and it is not big enough	It is okay but needs to be bigger. However, I want to see better methods of waste disposal
Background information about pilgrims	Fairly rich and well educated	Two different groups: 30% well educated and asked for better services whereas 70% were the opposite	Pilgrims came from very poor villages with very low level of education
Why did you support the idea	Hajj Ministry rating and media coverage	I always see this kind of project in their countries, so I want to see it in my country	Because I am looking for alternative methods for waste disposal
You opinion about the project, before implementing it	I thought pilgrims would not sort out their waste	Pilgrims will react to this project because of their background	I was afraid of the ignorance of the pilgrims in my camp
You opinion about the project, after implementing it	I was surprised by the results; also, pilgrims liked this project	Some pilgrims sorted their waste into the green bins, but the rest caused contamination	Surprised, as I saw pilgrims sorted their plastic waste, but I saw how others could not identify plastic
Media coverage	Increase the level of interest	Increase the level of interest	Increase the level of interest
Future expectation to sorting project	Implement this project in all camps especially the VIPs as they produce a huge quantity of plastic waste	Generalize sorting project to all camps and add third bin for paper and cardboard	Mina authorities should help in implementing this project in future

The interviews with the camp managers indicated that some of their prior opinions about how the project would work were not borne out by the results, and both the staff and the pilgrims in the camp liked this project. In addition, all of them agreed that this project could achieve greater success if it were supported by the Mina authorities. **Table 6-13** summarizes the answers of the three camp managers during the interviews, which were required to analyse some of the results. For instance, the pilgrims' social and educational levels were reported by the camp managers.

6-5 A Summary for the Key Findings in Chapter 6

This chapter presented the results of the exemplar project where recycling was introduced to the pilgrims in three camps (**OBJ4**). In addition, the relationship between the pilgrims' stated intention and actual behaviour was obtained (**OBJ5**). The key findings of this chapter are as follows:

1- Implementing recycling during the Hajj is feasible; the average percentage of the actual sorting behaviour was about 25%.

2- The pilgrims from Arabic countries sorted the highest percentage of plastic in the uncontaminated sorting bags and produced the lowest percentage of sorted plastic in the contaminated sorting bags.

3- Level of education affects actual recycling behaviour.

4- The differences between the percentages of sorted plastic based on the second sorting scenario for the three camps are not practical, but the differences between the percentages of sorted plastic in the uncontaminated sorting bags (SPU) between the three camps are considerable especially for the Pakistani camp (**Figure 6-9**).

5- Stated intention can strongly predict future behaviour if the stated intention is adjusted based on the existence of a recycling habit (the two habit scenarios, **Section 4-10**).

6- The overall predictive accuracy of pilgrims' stated intention (PASI) is about 79%.

7- The stated intention can be lower than the actual behaviour if the pilgrims do not have a background of recycling or they have fears regarding participation.
8- Controlling food catering in the Mina camps can increase the level of sorting and reduce waste generation.

CHAPTER 7

DISCUSSION

7-1 Introduction

In this chapter, the key findings in both results chapters (**Chapter 5** and **Chapter 6**) are discussed and compared with the literature, as reviewed in **Chapter 2**. As established in **Section 3-1**, to date there has been no academic research on the SWM system during the Hajj. The same applies to participants' opinions about recycling at mega events (Barber et al., 2014). Therefore, this research focuses firstly on establishing a background and assessing the current SWM in Mina (**OBJ1** and **OBJ2**), and mainly on the opinion of participants (pilgrims) towards recycling and waste sorting at source (**OBJ3**). It then compares and contrasts pilgrims' stated intention with their actual behaviour during the experimental introduction of a pilot (exemplar) recycling scheme (**OBJ4** and **OBJ5**).

As a result of the lack of data regarding the Hajj or big (religious) events, where suitable, the results are discussed based on any similar studies on cities or communities. In addition, potential explanations are put forward regarding the reasons for the differences between intention and behaviour (**OBJ5**). Finally, based on the data collected and novel insights obtained, suggestions on improving the level of recycling and on the deployment of a full scheme during the Hajj are highlighted.

7-2 Pilgrims' Sorting Stated Intention and Actual Behaviour in Mina

The results of the pilgrims' questionnaire (**Section 5-6**) as well as from the exemplar project (**Section 6-2**) demonstrated that the pilgrims' ethnicity affects recycling participation intention and behaviour, as Nixon and Saphores (2009) reported. On the other hand, many other researchers did not report any relationship between ethnicity and recycling participation. This could be a result of studying a community that contains people with no ethnic variation.

The effect of ethnicity on recycling intention during the Hajj can be seen in the pilgrims' questionnaire regression results, which showed that the pilgrims from Arabic countries had the highest intention to sort their waste whereas the pilgrims from western countries had the lowest intention to sort their waste. In addition, a similar variation can be seen in the results of the sorting project where the Egyptian pilgrims (from Arabic countries Tawafa Company) produced the highest percentage of sorted plastic (27%) while Western European and Australian pilgrims (from Western Countries Tawafa company) sorted less (26%) and the Pakistani pilgrims came last (24%) out of the three camps (**Table 6-10**). Although the difference between the results of the three camps is not practical, this was not expected, as many researchers have reported that people tend to sort more of their waste if they have a waste sorting habit (Knussen and Yule, 2008; Ittiravivongs, 2012).

It is unknown which group of pilgrims (pilgrims with or without a recycling habit) sorted their waste at the three camps. It is known from the pilgrims' questionnaire responses that about 86% of the Western European and Australian pilgrims had a recycling habit, but nonetheless, they sorted about the same amount as the Pakistani pilgrims of whom fewer than 30% had a recycling habit (**Table 6-11**). Thus, sorting behaviour cannot be compared with recycling habit (at least in the case of the Hajj) unless all the variables affecting both behaviour and habit are considered. For instance, regarding the nature of the Western European and Australian citizens' sorting habit, the percentages of plastic recovery from households in European Union countries and Australia were 21.3% in 2008 (European Commission, 2011) and 14% in 2011 (Randell et al., 2014) respectively with an average of about 18%. This average is less than the average percentage of plastic sorted by this group's camp (26%, **Table 6-10**), which might mean that, on average, the pilgrims' participation in the sorting project in Mina was better that their participation in their home country in terms of sorting plastic.

This might mean that the surrounding environment can affect individuals' recycling habit. In addition, it seems that these pilgrims were more motivated to sort their plastic at Mina than in their home countries, which might be due to the effect of religious motivation as explained in **Section 7-5-3**. In addition, it is expected that if these pilgrims were asked to put all of their recyclable waste into the sorting bins, their actual behaviour might be higher (as this is the common method of waste sorting in many developed countries). Therefore, all these variables should be looked at when studying the relationship between recycling behaviour and habit, especially during mega events.

However, the existence of a steady recycling habit had other influences on the pilgrims' sorting behaviour in the exemplar project. For instance, one of the important conclusions derived from the supervisors' notes was that the pilgrims with a limited (not steady) sorting habit (Egyptian and Pakistanis) reacted differently to this project during the three days in terms of the percentages of uncontaminated and contaminated bags. In the European camp, where most of the pilgrims had a steady sorting habit, the pilgrims produced the same percentage of uncontaminated bags for each of the three days whereas in the other camps (where most of the pilgrims did not have sorting habit), the pilgrims generated a different percentage of uncontaminated bags on each of the three days (**Section 6-2**). One interpretation of this result is that the pilgrims with a prior sorting habit in their home country did not change their sorting behaviour once they had started to participate even if the surrounding conditions were changed whereas the behaviour of the other pilgrims was influenced by changes in the surrounding circumstances and conditions. Therefore, it can be concluded that once pilgrims with a steady recycling habit start to sort their waste, they will probably continue to do so whereas pilgrims with only a limited or unsteady habit may change their minds and stop participating in the sorting project.

It was also essential to compare the pilgrims' sorting intention with their recycling habit to identify the relationship between them. In **Figure 5-45**, it can be seen that in the optional sorting part, the Egyptian pilgrims and the Western European and Australian pilgrims with a sorting habit had more potential to sort their waste whereas for the Pakistani pilgrims, there was not much change. However, in the compulsory part, the pilgrims with a sorting habit were much more positive than were the pilgrims with no sorting habit in all three groups.

This indicates that the motivation of pilgrims' habit affects their intention, as some pilgrims are forced by law to sort their waste in their home countries whereas this sorting project was optional. However, for the overall pilgrims it could be seen that pilgrims with a recycling habit had a more positive intention toward sorting their waste than had those pilgrims with no recycling habit in both parts (optional and compulsory). However, again, the compulsory sorting intention was higher than the optional. Based on these results and on the results of the multinomial logistic regression, it can be said that there was a statistically significant relationship between pilgrims' recycling intention and their habit, but this relationship needs to be investigated further, especially the motivation of the habit. This relationship between intention and habit is supported by many researchers, such as (Knussen et al., 2004; Knussen and Yule, 2008; Ittiravivongs, 2012).

The motivations of the pilgrims who said they sorted their waste in their home country were unknown as was the nature of their habit, such as how often, when, why, and if there was any financial benefit to the recycling habit. In addition, the pilgrims from developed countries (where waste separation at source is enforced by the law) need to be studied more in terms of their original nationalities and whether they represent the prevailing manners of the citizens in these counties. For instance, based on the interviews with the camp manager, most of the pilgrims who came from western countries were not originally from these countries but they were originally from Asian countries, such as Pakistan or India, or were from Eastern European countries (**Section 6-4-2**). Thus, it can be said that sorting motivation has an effect on recycling habit and, consequently, it may influence pilgrims' recycling intention and behaviour.

There were other important factors that affected the pilgrims' recycling intention and behaviour in Mina, such as their level of education, and some socio-demographic features, such as their level of income. Many researchers have reported that these two factors affect people's intention (Pieters and Verhallen, 1986; Schultz et al., 1995; Ekere et al., 2009). However, other researchers (Kok and Siero, 1985; Nixon and Saphores, 2009) have provided evidence of cases where it was not possible to establish a relationship between those two factors and the decision to participate in recycling. What is clear, is that this variation in the relationship between participating in a sorting project and other factors is subjected to the time and place of the project, as Schultz et al. (1995) found. In addition, Gonzalez-Torre and Adenso-Diaz (2005) suggested that each community has both different and similar factors to other communities that affect participation in a source separation project. Thus, there are some factors that affected recycling in the Mina camps during the Hajj that could not occur in any other place or event.

In addition, (based on the results of multinomial logistic regression for the pilgrims' questionnaire – **Section 5-6-2**), level of education and waste sorting intention (if it is compulsory) are positively related, which means that pilgrims with a higher level of education have a higher intention to sort their waste at source. In addition, in the optional sorting model, the postgraduate group had a higher intention to sort optionally than had the other three groups. However, the insignificant difference between the no degree group (the reference) and the university degree group might be due to interaction with other unrecorded factors. Thus, the relationship between intention to sort optionally and level of education groups needs to be studied and investigated more in future research. Based on this, it can be concluded that there is an interaction between the level of education and following the rules that are imposed by law. Thus, the more educated people are, the more likely they are to implement waste regulations.

Furthermore, based on the regression results (both models - **Section 5-6-2**), it can be seen that all the three chosen indicators for each country (GDP per capita, EPI, and the annual waste generated per capita) affected waste sorting intention positively, which confirms that some of the socio-demographic indicators have an effect on waste sorting intention (recycling participation). This is consistent with the concept of the extended Theory of Planned Behaviour (**Figure 2-2**).

Another important factor that has a significant effect on people's recycling participation is information campaigns and educational programmes (Thogersen, 1994; Zhuang et al., 2008; Nixon and Saphores, 2009). This finding was also demonstrated in the results of the pilgrims' questionnaire in the responses to questions 3 and 4, which showed that although 66% of the pilgrims said they had heard about waste sorting and recycling (question 3), 69% of them said they were able to sort after they had read the attached definitions for waste sorting and recycling (question 4) (**Section 5-6-1**). This means that more pilgrims may participate in the waste sorting and recycling project if they understand the concept and the benefits.

Finally, it is important to highlight that all the pilgrims who participated in the exemplar project showed more or less the same sorting behaviour; but the main difference between the three camps were in percentages of the contaminated and the uncontaminated sorting bags (**Figure 6-9**). In other words, taking into account all the different variables between the three camps, about 25% of the pilgrims in each camp sorted all of their plastic waste based on the assumption that all the pilgrims who participated in this project sorted all of their plastic waste (**Section 4-10**). This seems to support the conclusion that irrespective of the cause of their behaviour, the pilgrims reacted fairly well to this project. This might be because of the religious motivation, which was to give it to charity instead of throwing it away (as charity is very important in Islamic religion), or because of their realization of the need for change.

Table 7-1 summarizes the factors that affected the pilgrims' optional and compulsory sorting intention (**OBJ3**) as well as the factors that affected the pilgrims' sorting behaviour (**OBJ4**). It can be seen that if the sorting project is going to be generalized all over Mina camps, the variation in these factors between Mina camps should be considered. Thus, one recommendation is to design different sorting plans for each different group of pilgrims. These groups can be represented by the Tawafa companies, which mean there should be a special waste separation system for each Tawafa Company or for each similar group of Tawafa companies. However, there could be other unrecorded factors that might affect pilgrims' sorting behaviour in other Tawafa companies that were not covered in this exemplar project. Therefore, it is recommended that another exemplar project be applied in one or two camps in each Tawafa Company to record the common factors that affect each company.

Table 7-1 A summary of the factors that affected pilgrims' sorting intention (optional and compulsory) and behaviour in Mina during the Hajj

<table>
<tr><th rowspan="2">Factors that affected pilgrims' plastic waste sorting behaviour</th><th colspan="2">Factors that affected pilgrims' waste sorting intention</th></tr>
<tr><th>Optional sorting</th><th>Compulsory sorting</th></tr>
<tr><td>Level of education</td><td>Level of education (but not all levels have statistically significant difference, Section 5-6-2)</td><td>Level of education (higher level of education means higher intention to sort)</td></tr>
<tr><td rowspan="3">Pilgrims’ social level</td><td colspan="2">Pilgrims’ level of income (GDP/capita)</td></tr>
<tr><td colspan="2">Environmental performance index (EPI)</td></tr>
<tr><td colspan="2">Quantity of waste arising per capita in their households</td></tr>
<tr><td>The existence of a good motivation</td><td colspan="2" rowspan="4">Pilgrims’ ability to sort</td></tr>
<tr><td>Time to educate pilgrims (educational and informational campaigns) and perceive difficulty in communication (spoken languages)</td></tr>
<tr><td>Pilgrims could identify plastic</td></tr>
<tr><td>Level of disturbance during pilgrims’ arrival and departure</td></tr>
<tr><td rowspan="2">Quantity of generated plastic and the availability of free plastic bottled drinks refrigerators</td><td></td><td>Food Source</td></tr>
<tr><td colspan="2">Eating location (inside or outside camp)</td></tr>
<tr><td>SWM infrastructure in the camp as well as cleaning workers</td><td colspan="2">The level of satisfaction with the surrounding environment represented in level of cleanliness of Mina’s streets</td></tr>
<tr><td>Pilgrims’ interest in the project</td><td colspan="2">Waste sorting and recycling background</td></tr>
<tr><td>Pilgrim's ethnicity (but very limited)</td><td colspan="2">Pilgrims’ ethnicity</td></tr>
<tr><td>Recycling habit with consideration of the nature of the habit, motivation, regularity and surrounding environment</td><td colspan="2">Recycling habit</td></tr>
</table>

7-3 Comparison between the Pilgrims' Stated Sorting Intention and Actual Behaviour (Predictive Accuracy of the Pilgrims' Stated Intention)

It is believed that it takes time to adopt, acquire, understand and perform a new method to handle solid waste (especially source separation), which might explain the variance between recycling intentions and behaviour (Thogersen, 1994). However, Manski (1990) stated that the intention data derived from a survey is a poor predictor of future behaviour as the individuals themselves are poor at predicting their future behaviour. Other researchers have reported that there is a relationship between intention and behaviour (Fujii and Gärling, 2003; Ittiravivongs, 2012), and that stated intention can predict future behaviour but only with a limited degree of accuracy, which depends on the presence of the habit. Usually, studies tend not to investigate the predictive accuracy of people's claim or stated intention to perform a certain behaviour, but as SWM in Mina is unique, it was very important for this relationship to be studied (**OBJ 5**).

To study the difference between waste source separation intention and behaviour, the results of the three camps from the sorting project and the result of the pilgrims' questionnaire for the countries included in these three camps were compared in **Section 6-2-4**. The predictive accuracy of the pilgrims' recycling stated intention for the three nationalities groups in the exemplar project and for the overall pilgrims (79%, **Table 6-11**) indicated that the stated intention can predict future behaviour strongly (**OBJ5**). Nevertheless, great consideration should be given to the nature and motivation of the habit

It can be seen that the pilgrims' intention to sort their waste at source was better than the actual sorting behaviour except for the Pakistani pilgrims, who had a very poor intention to sort their waste at the outset (**Section 6-3**). This caused their recycling stated intention to be lower than their actual behaviour, which meant their predictive accuracy was above 100% (**Figure 6-11**). This seems to support the previous findings and concurs with what many researchers have suggested, that is, that the strength of the relationship between recycling intention and behaviour depends on the presence of a recycling habit, as more than 70% of these pilgrims did not have a recycling habit (**Table 6-11**) meaning (in this case) that the relation between intention and behaviour was weak. It is believed that their low willingness to recycle was caused by their fear of participating in such a project, or by their ignorance about waste sorting and recycling.

In contrast, the recycling habit of the Western European and Australian pilgrims (83% of them had a recycling habit) was much higher than that of the Pakistani pilgrims, which led to an increase in the strength of the relationship between recycling intention and behaviour, as 60% of the stated intention was performed as actual behaviour (**Figure 6-11**). This (again) seems to confirm that there was a strong relationship between the pilgrims' stated intention and their recycling habit.

On the other hand, when comparing the results of the Egyptian camp with those of the Western European and Australian camp, it can be seen that the relationship between the pilgrims' sorting intention and their behaviour became stronger with less of a presence of habit (**Section 6-3**). Thus, although many researchers have stated that with a higher level of recycling habit, the relationship between the stated intention and the actual behaviour becomes stronger (Knussen and Yule, 2008; Ittiravivongs, 2012), this research has found that this statement is too general and cannot be applied to all SWM systems, especially during mega events. This research has also found that if the motivation and the nature of the recycling habit are unknown, then the actual behaviour can be affected (may be lowered) by changes in the surrounding environment for individuals with a recycling habit.

Thus, it is concluded that (based on this case study) there is a strong relationship between recycling intention and habit and recycling intention can predict future behaviour, but the relationship between recycling behaviour and habit is subjected to other variables, such as the motivation and the nature of the habit (**OBJ5**). In addition, in some cases, individuals with no recycling habit can perform similarly to individuals who do have a recycling habit.

In this research, the pilgrims in the three studied camps sorted about 25% of their waste even with a great variation in their recycling habits (**Section 6-2-4**). However, the pilgrims with a recycling habit (Western European and Australian pilgrims) sorted their waste at the same rate on each of the three days whereas the pilgrims with less of a recycling habit did sort a similar amount of waste but at a different daily rate. Thus, the factors that affected the waste separation behaviour negatively in the three camps should be avoided or resolved to increase the recycling rate.

7-4 Causes of the Difference between the Pilgrims' Recycling Intention and Behaviour

Manski (1990) reported that people's future behaviour is partly affected by the conditions known to them at the time when their intention was measured. This could have a positive or a negative effect. For instance, pilgrims' intention might be negatively affected by their thoughts about how difficult or complicated this system is going to be, as they do not have any idea about it (such as the Pakistanis pilgrims' camp – **Section 6-3**).

On the other hand, Kok and Siero (1985) reported that intentions can differ from the actual behaviour because of the difficulties in participation, such as the location of the sorting bins, the time required for the process, or the cleaning of the sorted waste. In addition, Nixon and Saphores (2009) added to these difficulties other factors, such as the failure of the educational programmes and information campaigns, the presence of the rich mixture of ethnicities, the social interactions, and the effect of human emotions. Some of these factors were found to have an effect on the exemplar project (**OBJ4**). For instance, some of the pilgrims tended not to clean their sorted waste, which caused an increase in the percentage of contaminated bags. Furthermore, the presence of the huge mix of ethnicities might be another important factor in this process. However, Fransson and GÄRling (1999) reported that recycling behaviour is affected by knowledge, beliefs, responsibility, and threats to personal health but not by background factors. It is believed that a combination of both opinions affected the pilgrims' recycling behaviour in Mina during the Hajj (based on the observations and results).

7-5 Assessment of Solid Waste Management in Mina

7-5-1 Key Findings

During the processes of data collection and fieldwork, and as demonstrated by the data analysis and interpretation, it is evident that a main challenge with the existing SWM system in Mina is the proper management. It appears that the key focus of the Mina authorities is to remove all the generated waste from Mina's streets and camps; however, this occurs without much consideration being given to the opinions of the participants and stakeholders (e.g., pilgrims and camp managers) or with a basis on any fundamental analysis or, indeed, understanding of their behaviour. In addition, it can be argued that the environmental and wider sustainability aspects pertaining to the SWM have never been considered at any depth.

Specifically, the current SWM system in Mina has been never been researched in depth or with powerful data collection and analytical tools. As a result, for example, the authorities were not able to explain why they had been spending so much, but the waste was still accumulating, while at the same time, some of the compactor boxes were never being used to their full capacity. Here, the main problems with the compactor boxes and streets waste are identified and discussed as revealed by the data analysis.

Compactor boxes

Although 87% of the camp managers said they used the compactor boxes to dispose of their camp waste (**Section 5-5-1**), recent research (the first pilot research on Mina compactor boxes) found that in 2012, 83.7% of the Mina camps did not use the compactor boxes appropriately (Mashat, 2013), which resulted in about only 35% wt. of their capacity being utilised (**Table 5-17**). This seems to confirm the possibility that the camp managers' responses to some questions in the questionnaire were not accurate. It may have been they were reluctant / cautious in providing honest answers, in case these were forwarded to the Mina authorities.

Mashat (2013) found that most of the fully used compactor boxes came from the streets, not from the camps. As detailed in **Section 5-3-4**, about 25% of the compactor boxes were distributed in Mina's streets and the remainder (75%) in the camps. This means the used capacity of the camps' compactor boxes was less than 35%.

As mentioned in **Section 1-7**, Makkah Municipality did not study the idea of the compactor boxes before the system was implemented. Therefore, these boxes need to be reassessed, and Makkah Municipality should think about using bigger boxes. These boxes are recommended to be underground boxes because of the area limitations and the problems of odours and waste leachate. A review of the compactor system design to identify any types that are less prone to leakage would also be recommended.

One of the main causes of waste leachate is food residuals (**Figure 5-12**) as well as unused food, which may contain water or juice bottles (**Figure 6-6**). This problem can be seen from the responses to both the pilgrims' and the managers' questionnaires. For example, even though about 67% of the camp managers provided their pilgrims with all their meals (questions 1 and 2 in the managers' questionnaire), only 48% of the pilgrims said that they had all their food from the camps' catering alone (question 2 in the pilgrims' questionnaire). It seems that some pilgrims did not like the food provided by the camps' catering, leading them to throw that food away and buy the type of food they liked (similar to what happened in the Pakistani camp - **Section 6-2-3**).

Although organic waste was the largest single waste component in the camp waste, it is expected that the percentage of organic waste generated was higher than the amount found in the analysis conducted on camp compactor boxes. As observed (on-site observation), and as questions 6 and 11 in the camp managers' questionnaire indicated, some of the camps staff threw their organic waste (wet waste) outside the camp onto the street (**Figure 5-12**). This practice was possibly adopted because this kind of waste causes problems in the Mina compactor boxes, such as bad odours and leaks of waste leachate out of the compactor box (**Figure 1-21**).

The mean of the organic waste was around 30% wt. as received, whereas the group of Saudi pilgrims reported only 13%. However, Mashat (2011) found that 38.7% of the Saudi pilgrims' camps did not use their compactor boxes to dispose of their food residuals, compared to 31% of the other camps. The overriding conclusion from direct observation and Mashat (2011) survey is that the collection / storage / treatment of organic waste in Mina needs to be studied more thoroughly to find a better managing method. As mentioned in **Section 1-6**, there is no composting facility available in this part of Saudi Arabia, and marketing the product of composting process is not going to be feasible as this region is not agricultural; thus, other solutions should be considered.

There is some potential to decrease the amount of organic waste, such as (from anecdotal evidences from the camp managers) by serving food in appropriate quantities (open buffet) or by giving the excess food to charities or directly to poor pilgrims (as question 6 in the camp managers' questionnaire showed). However, this is likely to have only a marginal impact, and dedicated food waste collection systems need to be studied to see if better management methods can be identified. Such studies would need to include treatment options, and though the lack of markets for compost have been noted (**Section 1-6**), the separate collection and treatment of organic waste, even if solid outputs are disposed of in landfill, may be worthwhile if they resolve the utilization problems experienced by the compactor box system for the remaining waste. Directing the "wet waste" away from the other waste components may also facilitate recovering value from the "dry" fraction (e.g. via mechanical sorting/recycling) and building upon the experience gained through the plastic recycling exemplar project.

In terms of non-biodegradable waste, plastic came first with a percentage of 28%. As discussed in **Section 7-5-3**, many event organizers have started to eliminate the use of plastic at their events because it is made from non-renewable fossil fuel, is non-degradable, and as litter, causes problems to the environment (on land and in marine environments). Although the plastic waste generated in the Mina camps consists of many plastic components, this quantity of plastic should not be wasted. It is estimated that the quantity of plastic disposed of in the camps' compactor boxes was 567 t in Hajj 2010 (**Table 5-7**). However, when considering all of Mina's waste sources over the five-day period, the estimated total quantity of plastic disposed of in the landfill was 4775 t (**Table 5-7**).

Plastics are one of the more easily recognized of the commodity materials, and they are in demand for recycling, particularly in South East and East Asia (China). According to Velis (2014) and based on UN Comtrade (2013), the total quantity of exported plastic waste in 2012 was about 14.43 billion kg at a value of \$6.61 billion. This means each metric ton (1000 kg) of sorted plastic can be exported at prices of around \$450 t^{-1}, representing a potential revenue loss of about \$220,000 during the Hajj.

These were the factors that led this research to focus on finding a solution for plastic in the first instance, with a view to learning from the experience before extending the collection recycling scheme to other waste fractions in the future.

<u>Waste, littering and collection on Mina's streets</u>

As littering on Mina's streets was not the main scope of this research, the impact of the street cleaners and hence the "turn-over" of waste was not fully assessed. However, as a part of SWM in Mina, the quantities of waste in Mina's main streets were estimated (**OBJ1**). The figures presented in **Section 5-2** mainly give an estimate of the tonnage present at any given time on the streets. Analysis of each day's waste did not indicate any systematic increase in litter over the three days monitored. This suggests the street cleaners were managing to remove waste at more or less the same rate as it was being generated (their job is to sweep up and place the street's litter into bins or the street's compactor boxes).

Clearly, the estimate of the weights, coupled with the photographic evidence, suggests a working pattern that permits a significant accumulation at any given time and then a blitz clear up. A routine, constant clearing of litter over a shorter interval could be expected to keep a lower “base load” of waste on the streets than was evident from this survey, but this would only ameliorate rather than solve this problem. In addition, the sources of the streets’ waste (**Section 1-7-1**) need to be controlled, especially the waste disposed of by camps onto the streets. This can be done through improving the camp compactor boxes based on the consumers’ needs and opinions.

7-5-2 Wasteaware ISWM Benchmark Indicators

One of the main analysis approaches to implementing this framework is the comparison between the level of income and other indicators (Wilson et al., 2012; Wilson et al., 2013a; Hickman, 2014). As there is no fixed level of income for the pilgrims who form the Mina community, the relationship between the level of income and Mina Wasteaware ISWM Indicators was not defined. This is because the pilgrims’ lifestyle in Mina (e.g. accommodation, services, and consumption) is not controlled by the income level of the pilgrims’ country/city of origin, but rather these conditions are mainly in the control of the Mina authorities and the companies running the camps

Figure 7-1 shows the variety of the pilgrims’ 140 countries in terms of GNI per capita as well as the level of income for each country according to the number of pilgrims who performed Hajj in 2008, which was 1.7 million non-Saudi pilgrims (Khan et al., 2010). From this figure, it can be seen that most of the countries with more than 10,000 pilgrims came from lower-middle income countries. About 1.3 million (legal + illegal) pilgrims from Saudi Arabia, a country with a high level of income, but not environmentally developed, performed Hajj that year.

Based on the on-site observation and anecdotal evidence from Mina officials, pilgrims' expenditure during the Hajj does not depend on their level of income. Although many researchers have found that waste generation depends on the level of income (Irwan et al., 2012; Wilson et al., 2012; Hickman, 2014), this is for stable communities over prolonged periods. The quantity of waste generation in Mina was 0.92 $kg.p^{-1}.d^{-1}$ in 2010 which, according to Wilson et al. (2012), is typical of the daily generation rates for lower-middle income groups. Although the waste generated per pilgrim would suggest that the prevailing level of income is lower-middle, and hence consistent with the data for non-Saudi pilgrims shown in **Figure 7-1**, it cannot be said that the level of income in Mina is lower-middle. Therefore, it was decided to focus on comparing the performance of the other indicators with the findings of researchers who have used the Wasteaware method to assess SWM performance in different cities.

Waste collection coverage

The waste collection service in Mina is a service provided by the government of Saudi Arabia. As Saudi Arabia is considered a high-income country (World Bank, 2013), their waste collection coverage would be expected to be about 100%, based on Wilson et al. (2012) findings. This indicator was the only one to score 100% in Mina Wasteaware ISWM Indicators. Thus, it is concluded that collection service coverage was as expected, but the methods used need to be improved, as the percentage of waste captured by the compactor boxes and underground storage boxes was low (36%) with the majority of Mina's waste being collected manually by cleaning workers.

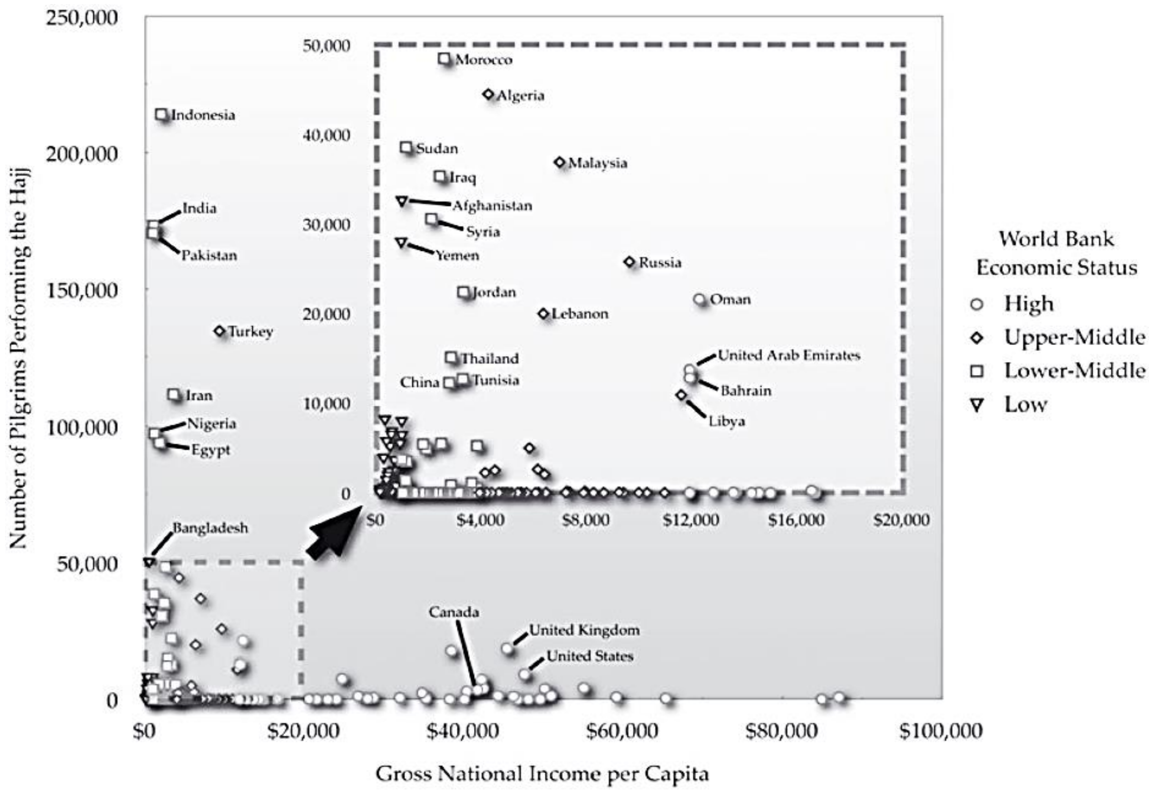

Figure 7-1 Number of pilgrims who participated in the Hajj 2008 against their country's level of income and GNI. Adapted from Khan et al. (2010)

<u>*Waste disposal*</u>

Although in Mina, waste is disposed of in Makkah landfill (simple controlled landfill), there is no treatment or separation for any type of waste (such as hazardous or organic wastes), and all waste arriving at the landfill is buried as it is. In addition, there is no monitoring of the surrounding environment, no controls on leachate or landfill gas, and no energy recovery at the landfill. However, based on Wilson et al. (2012) findings, it was expected a high-income country (Saudi Arabia) would have a better or more controlled method to dispose of waste. Wilson et al. (2012) reported that all high-income cities in the study used either state-of-the-art landfill (75%) or thermal treatment (25%) to dispose of their waste, not a simple controlled landfill as is used for Mina's waste.

(Wilson et al., 2013a) reported that the main reason for using a well-designed or engineered landfill is to protect the environment. Therefore, as a high-income city, Makkah Municipality combined with the Mina authorities are failing to match the benchmark for this indicator and should start protecting Makkah's environment by adopting / following the type of environmental legislation used in developed countries in terms of waste treatment and controlled disposal.

Recycling rate

Although in Makkah city, the informal recycling sector (IRS) is the only method for recycling waste, in Mina, there is no recycling, even by IRS. This means that all generated waste in Mina is buried in a simple controlled landfill, without any treatment or waste recovery. This might be a huge waste of resources and also endangers Makkah's environment, as Aziz et al. (2007) suggested.

Wilson et al. (2013a) found that, in 2009, on average, 15-54% wt. of the waste generated in 20 cities with different levels of income (low, lower-middle, upper middle and high) was recycled. In addition, Hickman (2014) found that the average recycling rate for 37 cities varied between 12% and 31% depending on the different levels of income. None of the 57 cities tested in the two previous studies scored 0%, the percentage for recycling in Mina. This means that if Mina is considered as a city, the authorities are failing to make even token progress on this indicator of a sustainable waste management system, and they need to start implementing waste recycling in Mina as one of the options to treat waste in Mina and recover resources.

Mina may have city "status" for five days per annum, but this occurs every year and clearly, recycling provision can be planned for. However, to implement recycling in

Mina, the authorities need to follow the steps of successful mega events as discussed in **Section 7-5-3** as well as getting benefit from the exemplar project implemented as part of this research.

User inclusivity, provider inclusivity

The user indicator score was 38% (low/medium) because the pilgrims were not included at all in the decision-making process whereas the provider inclusivity indicator score was 40% (low/medium) as the private sector was not included in this system. It seems that Makkah Municipality provides a good SWM service but does not consider the opinions or the feedback of the users (pilgrims) about the provided service; nor does it allow the private sector to participate in the SWM system in Mina.

Hickman (2014) obtained that the average score of the user inclusivity for 39 cities was 60% whereas the average provider inclusivity score was about 50%. Although these two indicators in Mina were below these averages, the Mina authorities can improve the scores of these indicators by including the private sector and the service consumers in the system planning and by considering their needs.

Engaging users of the service in design and delivery can improve commitment and desired behaviour (of both pilgrims and camp operators). In addition, private waste management and recycling companies may share their experience and knowledge with the Mina authorities, especially in the poorly scored indicators, where the authority may have a lack of knowledge.

Financial sustainability

This indicator score of 55% (Medium) in Mina was because the government covers all the costs of SWM in Mina without any cost recovery or return of benefits. It was observed (based on the interview with Mina official (Alsebaei, 2010), and from on-site observation) that Makkah Municipality does not seem to mind spending a large amount of money on SWM in Mina without any cost recovery to make the waste less visible during the Hajj event. Nonetheless, even these efforts fail as the waste is still accumulating in the streets (**Section 5-2**).

Wilson et al. (2012) reported that 18 of the 20 cities investigated were using different methods to ask their citizens to pay for SWM services. The basis for charging is not simply to raise revenue but to focus users' attention on the fact that it is their waste, and they need to take a measure of responsibility in terms of managing it in an environmentally and economically sustainable manner. Therefore, the Mina authorities should consider imposing a waste fee on each camp manager in order to encourage the managers to control the waste generation rate at their camps (especially food residuals), promote segregation for recycling, and cover a part of the cleaning contract in Mina.

Sound institutions, proactive policies

1- *National SWM framework*

It is obvious from the score of this indicator (25%, low) that there is a major problem with Mina's SWM regulations and the regulators, the policies, and the strategy plan. Wilson et al. (2013a) reported that to reach a proper control in SWM, it is necessary to formulate a strong and clear institutional framework. Thus, it is essential that the Mina authorities start to reconsider their entire SWM system in Mina environmentally and economically. To achieve this, Wilson et al. (2013a) stated that "*a city needs to address underlying issues relating to management structures, contracting procedures, labour practices, accounting, cost recovery and corruption*".

2- *Local institutional coherence*

The score of this indictor was 71% (medium/high), which means it was acceptable but might need some improvement in terms of producing reports with accurate data about the detailed situation of SWM in Mina. This report should formulate full background information about SWM in Mina, which is essential for any improvement to the system.

Summary of Wasteaware ISWM Indicators Benchmark findings

Wilson et al. (2013a) concluded that a "*successful solid waste management system needs to address both the physical (technical) elements (collection, disposal, recycling) as well as the 'soft' governance aspects*". Thus, based on all collected data about SWM in Mina and the results of the Wasteaware ISWM indicators, it was found that the main problem with the SWM system in Mina is the poor planning especially in the environmental aspect. There is sustainable finance, sound institutions, and sufficient labourers in Mina, but there is no proper environmental legislation or strategy for waste treatment or controlled waste disposal (**Section 5-4**). Thus, based on the results of this framework, it was revealed that the main problems with the SWM system in Mina are the lack of controlled waste disposal, poor initial management and collection systems, no provision of the preferred hierarchy options of recycling and treatment, and an inadequate national SWM framework. These problems were the main core of the planning for the exemplar project where the possibility of changing the current situation was tested.

7-5-3 Other Mega Events

Although SWM system in Mina is very basic, it costs too much without returning any profits and it affects the environment negatively. Based on the literature, the organisers of mega gatherings and events (such as the Olympics) are usually concerned about establishing a proper SWM system for the event to produce zero waste and recycle the most of the waste generated during the event.

However, other pilgrimage events, such as World Youth Day (WYD, for Catholic) and Kumbh Mela (for Hindus), are the most similar to the Hajj, where millions of people are gathered in a specific city or in sacred places for several days. In Kumbh Mela, there is not much effort made in terms of waste management, where the main related research aimed to identify waste quantities and composition (see (Gangwar and Joshi, 2008; Kaushik and Joshi, 2011). However, recently, a plan was developed to make Kumbh Mela 'green', that is, environmentally friendly, by focusing, in terms of solid waste, on stopping the use of plastic and on treatment of the biodegradable waste (Sarkar, 2014).

Similarly, since 2000, the organizers of the WYD event have started to assess the environmental impacts of the event on the city of Rome where the event took place in that year. This made it the first religious event to consider the environmental aspects in its plan (Caratti and Ferraguto, 2011). However, one of the most important problems for WYD in Rome (2000) was the coordination between the different institutional authorities, as the organization of the event was distributed between Rome City

Council, the regional government, and the Province of Rome. This was solved by developing strategic evaluation documents that established a technical reference for coordination (ibid). This seems a reasonable solution for the problems between the different institutions forming the Hajj authorities.

The effort on waste control and management continued in the WYD event where in 2013 during WYD in Rio, the organizers used the Italian bioplastic (completely biodegradable and compostable material). However, they tested it before the event in an exemplar project implemented in the Pontifical Catholic University in Rio de Janeiro among a group of young people (Novamont, 2013). According to WYD (2011), all pilgrims in WYD-Rio 2013 were also asked to fundraise by recycling their cans at a nearby drop off aluminium recycling centre in Lincoln. Using religious motivation seems to be a good method to increase participation in waste sorting projects, and a similar approach was adopted for the sorting project in Mina.

Although there are similarities between the Hajj and other pilgrimage events, the quantities of waste generated during these events are completely different. For instance, according to Salt and Light (2013), the quantity of waste generated during WYD-Rio 2013 was about 490 t (91% organic waste) generated in 5 days by 3.7 million pilgrims; whereas during the Hajj 2010, a similar number of pilgrims (3.69 million) generated about 35 times more waste (17052 t with about 29% wt. as received, organic waste) in the same period of time. In addition, although it was reported that in Kumbh Mela in 2007, about 8 million pilgrims generated an average daily waste of 300 t (51.8% organic waste) during the main days of the event in an area of 12.5 km^2 (Gangwar and Joshi, 2008), in Mina during the Hajj, 11.4 times more waste was generated daily by less than half the number of pilgrims and in a smaller area of 8 km^2.

The comparison between the three pilgrimage events shows that organic waste is the largest component in their wastes. The averages for daily organic waste generated in the three events were WYD-Rio 90 t, Kumbh Mela 155 t, and the Hajj 990 t. Although the percentage of organic waste generated during the Hajj was the lowest of the three events, its quantity was by far the greatest. Similarly, plastic waste represented 6.4% (19 t daily) of the waste generated in Kumbh Mela whereas in Mina during the Hajj, plastic waste represented about 28% (955 t daily). This means that, on average, fewer than 4 million pilgrims in Mina generated 50 times more plastic daily than did 8 million pilgrims in the Kumbh Mela event. This seems to support the need for better planning for SWM in Mina and for control of the entering procurements to Mina to minimise or prevent waste (as detailed in **Section 2-2-5**), which has the highest rank in waste hierarchy as the top waste management option (Melki, 2014). In addition, choosing re-usable and recyclable materials (3Rs) can reduce the huge quantity of waste disposed of in the landfill.

To develop SWM in Mina, the plan should follow the positive example set by green mega events. All the successful green mega events started by developed a successful SWM and its infrastructure in the city where the event took place. For instance, before the Beijing Olympics started, the whole SWM in Beijing city was reinvented with the help of UNEP to include the 3Rs, and it was then tested in an exemplar project before it was extended to the Olympics to ensure that they would have the proper infrastructure and that everyone would know about the system (**Section 2-6-2**).

Similarly, in the London Olympics, although the recycling infrastructure was already there, the SWM system for the Olympics was tested in exemplar projects before it was implemented in the event. In both Olympics, as a part of the green event preparation, massive informational and educational campaigns about the system were implemented to give the visitors an idea about the recycling system and its goals and benefits. In addition, Kaushik and Joshi (2011) reported that using the environmental impact assessment (EIA) methodology should minimize the problems resulting from SWM during big events and allow for better management.

Therefore, the importance of implementing an exemplar project during the Hajj to test pilgrims' ability to sort their waste at source emerged. Such a project should be implemented by or under the supervision of the authority or the organizers. However, this was not the case in Mina, as the Mina authorities did not support this research exemplar project.

This pilot project tested the pilgrims' ability to sort their waste at source. Even with a short educational campaign and limited infrastructure, about one quarter of the pilgrims sorted their plastic waste. This means that implementing the 3Rs in Mina seems to be feasible as well as desirable. Thus, the authorities should start changing the SWM in Makkah city by considering green and environmentally friendly waste disposal methods (such as waste sorting at source and recycling). They should develop a proper infrastructure for this system and then generalize it to Mina.

In addition, it is recommended that the Hajj authorities take advantage of the experiences of other events and try to get help from one of the international environmental organizations, such as UNEP. However, until a recycling project is fully implemented in Mina, consideration should be given to ending the use of non-biodegradable materials, such as plastic and metals, and using bioplastic instead, as the organisers of the other two pilgrimage events have found that it is an environmentally friendly solution.

7-6 The Wider Applicability of the Methodology and Results

Although this research focused on SWM in Mina during the Hajj and introduced recycling during this event, it has wider implications. For instance, recycling methodology and the exemplar project can be generalised and applied in similar mega events where visitors stay in tents or camps for several days. In addition, the methodology developed in **Section 4-10** to compare the stated recycling intention with the actual behaviour can be applied in any other case/community in which recycling strategies have not yet been implemented. In such cases, community members can be asked about their intentions to participate in sorting and recycling activities and then their actual behaviour can be identified when recycling projects are implemented on the ground. Moreover, the methods used in this research aimed at identifying factors affecting people's stated intention (**Section 4-8**) and actual behaviour (**Section 4-9**) can be used in any other case/community.

7-6-1 Recycling at Mega Events

This research critically reviewed the published literature and investigated the applicability of waste recycling on the ground during mega gatherings such as pilgrimage events. It found that visitors could adapt their behaviour to meet requirements from recycling systems, even if some of them have no previous experience/background in waste sorting and recycling.

However, it is very important to consider all of the factors that affect visitors' recycling intentions and behaviour. Some of the factors found in this research are related only to the Hajj, e.g. diverse methods of food catering in Mina camps, but the others can be generalised to any other case/community or mega event. These factors include the following:

- People's level of education
- People's socioeconomic status
- The educational and informational campaigns that are deployed
- The existence of a good motivation for people to participate in recycling
- The availability of the materials that are needed to be sorted at the source
- The existence of a convenient SWM system with a proper infrastructure
- Diverse ethnic backgrounds
- Recycling habits, but with consideration given to the motivations behind and the nature of these habits

Some of the previous factors might not have an effect on recycling intention and behaviour in a certain community because there might not be diversity among the people in same community. For instance, people in a certain community can have a similar socioeconomic status or they can all be from the same origin. Many researchers supported this reasoning; they found that the factors that can affect recycling intention and behaviour are subject to the conditions of time and place (Schultz et al., 1995; Gonzalez-Torre and Adenso-Diaz, 2005).

7-6-2 The Prediction of Recycling Actual Behaviour from Stated Intention

The relationship between stated intention and actual behaviour (generally) has been always controversial. However, to the best of the researcher's knowledge and based on the literature review (**Section 2-3-4, Section 4-10, and Section 7-3**), stated recycling intention has never been compared with actual behaviour during mega events. One of the reasons this comparison has never been made for mega event is, as Barber et al. (2014) reported, because visitors' recycling intention in general has never been studied.

Based on the findings of this research, stated intention can be a good predictor of future behaviour if the stated intention is adjusted based on the methodology developed in this research (**Section 4-10**). This is because the existence of recycling habits was considered in developing this methodology as well as the possibility that some people will change their minds. Therefore, it seems that this methodology (**Section 4-10**) can be used to predict future recycling behaviour for any community that does not have a recycling system to test people's ability to participate in a recycling system. In addition, based on this methodology, factors that have an effect on stated intention or actual behaviour can be identified.

CHAPTER 8

CONCLUSIONS AND RECOMMENDATIONS

8-1 Conclusions of Mina SWM Assessment

Assessment of the SWM system in Mina was derived from fieldwork, Wasteaware ISWM Benchmark Indicators, and comparisons of the Hajj with other mega events and pilgrimages. On this basis, the following conclusions have been drawn:

- The main weaknesses in Mina's SWM are the lack of controlled waste disposal; there is no waste recovery or recycling, and the current national SWM strategy is inadequate regarding environmental protection (**Section 7-5-2**) (**OBJ1**).
- Although the number of pilgrims attending the Hajj (in Mina) was the lowest of the three compared pilgrimages / religious events, the pilgrims in Mina during the Hajj generated far more waste than did pilgrims to the other events (**Section 7-5-3**), which indicated that more control on the procurements and the packaging in Mina are required to minimise waste production (**OBJ1**).
- Only about 36% of the waste generated in Mina (17 kt) was captured by the waste collection system (compactor boxes and underground storage boxes); the rest was collected manually (**Table 5-17**). In addition, less than the half of the boxes' capacity was used (because of the problems associated with them: waste leachate and bad odours), but even if the whole capacity of these boxes were used, it would not be enough to fit all the waste generated in Mina (**Table 5-17**) (**OBJ1**). Camp managers

supported these findings: about 55% of them thought the capacity of the compactor box was not sufficient (**Section 5-5**) (**OBJ2**).

- The main components of waste generated in the Mina camps (which represent 82% wt. as received) were organic waste (29%), plastic (28%), and paper and cardboard (25%) (**Figure 5-8** and **Table 5-7**). The quantities of these components in Mina are considerably more than in other pilgrimage events, which indicates that there is no minimization or even control of waste production in Mina during the Hajj (**Section 7-5-3**) (**OBJ1**).
- About 38% of the pilgrims were not satisfied with the level of cleanliness of Mina's streets, and about 40% of the pilgrims were not satisfied with the level of cleanliness in their camps (**OBJ2**).

8-2 Pilgrims' Stated Sorting Intention and Actual Behaviour Conclusion

This research has constructed a benchmark for waste sorting and recycling for the Hajj in Mina. Therefore, based on the results of the pilgrims' questionnaire and the exemplar project, the following conclusions were drawn:

- The pilgrims have a greater intention to sort their waste when it is compulsory (60.4%) than when it is optional (44.4%) (**Figure 5-44**) (**OBJ3**).
- Factors that affect pilgrims' optional sorting intention are slightly different from the factors that affect compulsory sorting, but overall, the following factors affected pilgrims' intention to recycle: level of education, social level (represented be GDP per capita, EPI, and the annual waste generated per capita), ethnicity, the method of food catering inside the Mina camp, waste sorting and recycling background and habit, information campaigns and educational programmes, and pilgrims' satisfaction

with the level of cleanliness of Mina’s streets (the surrounding environment) (**OBJ3**).

- The stated intention is highly correlated with the presence of a recycling habit, but the relationship between recycling behaviour and habit is subjected to other variables, such as the motivation, the nature of the habit, and the surrounding environment (**OBJ5**).
- It is proved that implementing recycling during the Hajj is feasible, as the average percentage of the actual sorting behaviour was about 25% (**Table 6-10** and **Figure 6-10**) with no practical difference between the group practicing recycling at home and other that do not. This percentage can be increased by resolving the difficulties that the pilgrims faced in this project: misunderstanding what type of waste they should sort, general waste bins being full, (sometimes) camp cleaning workers not being very collaborative, camp general waste bins’ limited capacity, a great diversity in the methods of food catering, and difficulty in communication because of the multilingualism (**OBJ4**).
- The predictive accuracy of the overall pilgrims’ stated intention (where the pilgrims’ stated intention was adjusted based on the findings of Fujii and Gärling (2003), **Section 4-10**) was about 79% (**Table 6-11** and **Figure 6-11**); this indicates that the stated intention can predict future behaviour strongly, but the accuracy might be affected by the nature and motivation of the pilgrims’ recycling habit, the lack of a recycling habit, and fear of participating (**OBJ5**).
- Pilgrims will participate in waste recycling if they are motivated (especially by religious motivation); thus, it is concluded that sorting motivation may change the recycling habit, and consequently, it may influence pilgrims’ recycling intention and

behaviour. Furthermore, people with no habit can perform similarly to people who have a recycling habit if they are highly motivated (**OBJ5**).

- A well-organized informational and educational campaign seems to increase the percentage of pilgrims' participation in recycling projects (**OBJ5**).
- Once pilgrims with a steady recycling habit start to sort their waste, they are very unlikely to stop whereas pilgrims with a limited or unsteady recycling habit may change their minds and stop participating in the sorting project (**Section 7-2**) (**OBJ4**).

This research's main contribution is that the methodology developed in **Section 4-10** to compare people's stated recycling intention and actual behaviour (**OBJ5**) can be implemented in any other case/community. This can predict future recycling behaviour based on stated intention, which should be helpful in designing such a project. In addition, the design of the recycling exemplar project used in this research (**Section 4-9**) can be implemented in any other similar mega event.

8-3 Recommendations for the Mina Authorities to improve the SWM System

The following recommendations are made to develop SWM in Mina based on the results of this research:

- The waste storage boxes should be separate underground boxes where sorted waste can be stored separately and the problems of odours and waste leachate can be reduced or eliminated. Initially, it is recommended installing two separate underground boxes for each camp and allocating a trained member of the camp staff to operate these boxes and ensure that the sorted waste is not contaminated with other waste. In addition, a review of the compactor system design to identify any types that are less prone to leakage is also recommended.

- The Hajj Ministry, Makkah Municipality, and other related organizations, including the Mina authorities, should cooperate together to establish a proper framework for SWM in Mina based on the experience of organisers of other mega events under the supervision of one of the international environmental organizations.
- Camp managers should be motivated to clean the streets in front of their camps as the managers of some VIP camps do (**Figure 5-2**).
- A waste recycling system should be established in Makkah city and extended to Mina with a proper infrastructure, as has happened in other mega events, such as the Olympics. It is preferable to start implementing a waste sorting project in the Mina camps and to study the possibility of extending it to Mina's streets.

In addition, the following recommendations may have a positive effect on waste recycling in Mina:

- Stimulate the Mina authorities to enact a law that obliges pilgrims to sort their waste at their camps when a full-scale recycling project is implemented in Mina.
- Customize a special design for beverage refrigerators in the Mina camps by attaching a special container to the refrigerators to throw empty plastic bottles and cans into it.
- Use educational campaigns to educate pilgrims about the importance of waste sorting and recycling (after installing a proper waste recycling infrastructure).
- Control the materials used in food catering and food shops to minimise waste production, and use a recyclable materials (the 3Rs).
- Put different recycling plans for each Tawafa Company based on the predominant characteristics of the pilgrims. As a start, two plans are recommended: one basic and

one advanced. In the basic plan, pilgrims should be asked to put their food residuals and wet waste into the general waste bin and to put dry waste in the recycling bin where it can be sorted later in the material recovery facility (MRF). However, in the advanced plan, plastic should be collected separately from the dry waste; therefore, in this plan, three bins are needed at each location.

8-4 Suggestions for Future Research

The suggestions for future research are based on the questions arising from the conclusions drawn in this research or through the knowledge gaps that have been identified, but have not been investigated in this study due to the research limitations. Therefore, the future research recommendations are as follows:

- Adjust Wasteaware ISWM benchmark indicators so they can be used to assess SWM in mega events, taking into account the multicultural nature of the community.
- Investigate the relationship between the nature and motivation of pilgrims' recycling habit and their waste sorting intention and behaviour as it is found that the relationship between recycling habit and behaviour is dependent on these factors and perhaps on other unrecorded variables.
- There is a need to study the differences between real waste sorting behaviour if the project is optional or compulsory, as it is found that there is a difference between the pilgrims' sorting intention depending on whether the project is optional or compulsory.
- Pilgrims from developed countries need to be studied more in terms of the effect of their original nationalities on their recycling decision and if they represent the predominant manners of the original citizens of the developed counties.

- A detailed survey should be designed to identify the relationship between level of education and sorting intention and behaviour (optional or compulsory) as it is unknown whether pilgrims intend to sort (when it is compulsory) because of their understanding of the rules or because of their awareness of the environmental importance of waste recycling. This may help in designing a better recycling system.
- Another exemplar project should be applied in one or two camps in each Tawafa Company to monitor sorting behaviour and record the factors that affect it in each company.
- An environmental impact assessment study should be implemented for the current SWM in Mina and any other suggested plans for the system's development (such as recycling).
- Research should be conducted into the difference between waste sorting intention and behaviour for pilgrims who have a recycling habit from developed and from developing countries as it is found that the sorting habit for pilgrims from developing countries is unsteady or is dependent on the conditions whereas the habit of pilgrims from developed countries is steadier (they are usually forced to sort their waste by law).
- The value and perceived impact of the factors that affect pilgrims' sorting behaviour should be identified.

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APENDIX A

MINA'S CAMPS AND STREETS WASTE

Table A1 The sorting form used to identify Mina camps waste composition

Camp :	***Compactor box No.:***	***Number of collected bags:***	
Material	**It contains**	**Weight**	**Note**
Organic waste	Food residual and other organic		
Plastic	Plastic bottles, plates, spoons, other hard plastic		
Plastic film	Packaging nylon + disposable plastic table sheets and plastic bags		
Paper and cardboard	Paper juice bottles, cardboard and other kind of paper		
Glass	Any kind of glass		
Cans	Aluminium cans containing carbonated beverages		
Aluminium foil	Just aluminium foil		
Other metals	Such as food tin and ferrous metal		
Cork	Cork and cork plates		
Textile	Textile, leather, mats and clothes		

Table A2 The weight (kg) and time of collection of each collected sample from Alkaif Street

Date	Alkaif Toilet				Second Place				Third Place				Fourth Place				Fifth Place			
	Time	*L*	*C*	*R*	*Time*	*L*	*C*	*R*	*Time*	*L*	*C*	*R*	*Time*	*L*	*C*	*R*	*Time*	*L*	*C*	*R*
2010/11/16	13:35	2.5	0	3	13:39	0.1	0	1	13:45	0.4	0	0.5	13:50	0	0	0	14:00	1	0	0
	14:30	2	0	1.5	14:35	0.5	0	5	14:45	4	0	0	15:00	0.5	0	0	15:10	0	0	0
	15:00	3	0.1	1.4	15:30	4	0	3	16:00	3	0	0.1	16:30	0	0	0.1	17:00	0	0	0
	18:00	1.9	0.1	1.2	18:25	0.2	0.1	4	18:50	0	0	0	19:15	0.1	0	0	19:45	0.2	0	0
	20:15	2.3	0	4	20:35	0.2	0	2.5	21:02	0.2	0	1.3	21:25	2	0	0.5	22:00	0	0	0
	23:05	2.2	0	3.5	23:29	1.6	0	0.3	23:52	0.3	0	0.1	00:14	1.5	0	0	00:30	0	0	0
2010/11/17	01:00	0.5	0	2	01:10	0.5	0	3	01:15	2	0	0	01:21	0.5	0	0	01:25	0	0	0
	01:51	0.3	0	2	02:00	4	0	0.5	02:07	3	0	0	02:12	0.6	0	0	02:15	0	0	0
	09:15	3.1	0	2.5	09:40	0.4	0	0.3	10:00	3.5	0	3.9	10:15	1.5	0	1.3	10:30	0	0	0.2
	13:05	0.4	0	3	13:30	0.3	0	2.5	13:50	2.3	0	3.6	14:10	0.2	0	0	14:27	0	0	2.3
	19:00	2.3	1.3	3	19:50	1	0	5	20:35	1.1	0	1.3	21:15	0.2	0	5.1	22:00	1	0.3	0
	22:40	0.4	0.2	3.2	23:15	3.1	0	0.3	23:40	0.2	0.1	2.2	00:10	5.4	0	0	00:35	0.3	0	1
2010/11/18	00:50	0.2	0	3.9	01:14	3.7	0	0.4	01:38	2.5	0	0	01:49	5	0	0	02:05	0	0	0
	03:05	3	0	2.9	03:23	0.3	0	4.5	03:40	3.2	0	0	04:00	0.4	0	0	04:20	0	0	0
	08:00	2	0	0.5	08:08	0.5	0	2	08:15	2.3	0	1.5	08:21	1	0	2.5	08:26	0	0	0
	09:00	2.4	0	4	09:20	2.5	0	0.5	09:45	1	0	1	10:00	1	2	0	10:15	0	0	0
	14:00	3.4	0	2.2	14:35	5	0	2.3	15:00	6	0	0.1	15:40	4	0	0	16:00	0	0	0.2
	16:30	17	0.2	6	17:15	0	0	0	17:50	4	0	3.2	18:20	0.3	0	0	19:00	0.4	0	0
Total (kg)		**48.9**	**1.9**	**49.8**		**27.9**	**0.1**	**37.1**		**39**	**0.1**	**18.8**		**24.2**	**2**	**9.5**		**2.9**	**0.3**	**3.7**
Average (g)		**2716.7**	**105.6**	**2766.7**		**1550.0**	**5.6**	**2061.1**		**2166.7**	**5.6**	**1044.4**		**1344.4**	**111.1**	**527.8**		**161.1**	**16.7**	**205.6**

Table A3-a The weight (kg) and time of collection of each collected sample from Souq Alarab Street (five places)

Date	King Khalid Bridge				Second Place				Third Place				Fourth Place				Fifth Place			
	Time	*L*	*C*	*R*	*Time*	*L*	*C*	*R*	*Time*	*L*	*C*	*R*	*Time*	*L*	*C*	*R*	*Time*	*L*	*C*	*R*
2010/11/16	13:00	2.5	0	1	13:20	5	0	4	13:45	0	0	3	14:15	9	0	3	14:40	1.5	0	2
	16:20	4	0	4	16:35	4	0	4	16:50	0	0	3	17:05	0	0	3	17:15	0	0	0
	18:20	9	0	8	18:30	1	0	0	18:40	1	0	2	19:00	1	0	3	19:15	2	0	4
	20:00	0	0	1.5	20:20	0.25	0	0.5	20:40	0.5	0	3.5	21:30	0	0	0.5	22:00	0	0	0
	23:25	0	0.5	0	23:41	2	0	0	23:53	3	0	2	00:15	4	0	3	00:29	4	0	2
2010/11/17	01:00	2	0	1	01:30	4	1	4	02:00	1.5	0	8	02:30	1	2	5	03:00	2	0	0
	05:15	0	0	0	05:30	0	0	0	06:00	0	0	0	06:30	0	0	11	07:00	2.5	0	0
	09:10	0	0	0	09:35	0	0	5	09:45	0	0	4	10:00	0.5	0.25	2	10:20	0.25	0	0.5
	11:15	0	0	0	11:30	0.25	0	0	11:40	0	0	4.5	12:00	1	0	2.5	12:15	3	0	2.5
	16:45	3	0	0	17:00	11	0	12	17:15	14	0	13	17:35	0	0	6	17:55	0	0	4
	19:45	10	0	9	20:10	0	0	0	20:40	7	0	3	21:00	4	0	0	21:30	0	0	0
2010/11/18	00:30	2.5	0.5	1	00:45	0	0	5	01:05	1.5	0	10	01:30	0	0	0	01:50	0	0	0
	03:20	0	0	2	03:50	0	0	0	04:15	3	0	2	04:45	0	0	0	05:10	0	0	0
	07:05	1.5	0	1.5	07:30	5.5	0	0	07:54	4	0	3	08:25	4	0	2.25	08:50	2	0	1
	10:42	5	0	1	10:58	4	0	2.5	11:18	3	0	2	11:40	2.5	0	2.5	12:15	1	0	1.5
	15:00	6	0	1	15:20	2	0	1	15:45	0	0	7	16:10	0	0	0	16:45	0	0	0
Total (kg)		**45.5**	**1.0**	**31.0**		**39.0**	**1.0**	**38.0**		**38.5**	**0.0**	**70.0**		**27.0**	**2.3**	**43.8**		**18.3**	**0.0**	**17.5**
Average (g)		**2843.8**	**62.5**	**1937.5**		**2437.5**	**62.5**	**2375.0**		**2406.3**	**0.0**	**4375.0**		**1687.5**	**140.6**	**2734.4**		**1140.6**	**0.0**	**1093.8**

Table A3-b The weight (kg) and time of collection of each collected sample from Souq Alarab Street (the rest three places)

Date	Sixth Place				Seventh Place				King Abdullah Bridge			
	Time	*L*	*C*	*R*	*Time*	*L*	*C*	*R*	*Time*	*L*	*C*	*R*
2010/11/16	15:00	2	0	1.5	15:20	3	0	10	15:40	5	0	3
	17:30	0	0	1	17:40	0	0	0	17:50	2	0	0
	19:30	9	0	4	19:40	0	0	0	19:50	0	0	0
	22:25	0	0	0	22:49	0	0	0	23:12	3	0	1
	00:40	2	0	2	00:48	0	0	0	00:55	5	0	4
2010/11/17	03:30	1.5	2	4	04:00	0	0	0	04:30	8	0	8
	07:30	0	0	0	08:00	0	0	4	08:30	9	0	0
	10:30	0.25	0	1.5	10:35	0	0	0.5	10:42	0	0	0.5
	12:25	5	0	2	13:00	4.5	0	5.5	13:30	0.5	0	1.5
	18:15	10	0	0	18:30	0	0	0	18:45	2	0	10
	22:00	0	0	0	22:30	0	0	0	23:00	0	0	9
2010/11/18	02:20	0	0	0	02:40	0	0	0	02:55	1.5	0	1.5
	05:40	0	0	0	06:00	0	0	0	06:20	2.5	0	2
	09:15	0.5	0	0.5	09:35	3	0	5	10:13	3	0	1
	12:40	1.5	0	0.5	13:09	3	0	4	13:20	5	0	4
	17:15	0	0	0	17:25	0	0	0	17:40	6	0	3
Total (kg)		**31.8**	**2.0**	**17.0**		**13.5**	**0.0**	**29.0**		**52.5**	**0.0**	**48.5**
Average (g)		**1984.4**	**125.0**	**1062.5**		**843.8**	**0.0**	**1812.5**		**3281.3**	**0.0**	**3031.3**

Table A4 The compactor boxes weight in the 32 camps and the number of bags collected in each sample and their ratio

Tawafa Company	Country	Number of bags	Sample Total Weight (kg)	MCW (t)	XCW (t)	Sample ratio (MCW) (% wt. As received)	Sample ratio (XCW) (% wt. As received)
Arabian Countries	Sudan	10	72	1.1	2	6.5	3.6
	Egypt	5	21.1	2.1	3	1.0	0.7
	Somalia	8	60.6	0.1	1	60.6	6.1
	Lebanon	15	83.05	3.1	4	2.7	2.1
	Algeria	6	45.6	2.1	3	2.2	1.5
	Tunisia	10	58.7	0.1	1	58.7	5.9
	Syria	7	43.9	1.1	2	4.0	2.2
	Kuwait	5	22	5.1	6	0.4	0.4
	Oman	15	73.23	1.1	2	6.7	3.7
	Qatar	7	36.7	3.1	4	1.2	0.9
	Palestine	12	45.9	3.1	4	1.5	1.1
	Iraq	10	37.7	3.1	4	1.2	0.9
South East Asian	Indonesia	15	63.1	8.1	9	0.8	0.7
	Singapore	15	58.5	6.1	7	1.0	0.8
	Malaysia	5	19.7	4.1	5	0.5	0.4
South Asian	India	5	24.5	1.1	2	2.2	1.2
	Emirates	5	16.7	1.1	2	1.5	0.8
	Pakistan	6	21.1	3.1	4	0.7	0.5
Turkey and Muslims of Europe, Americas and Australia	Turkey	15	69.1	2.1	3	3.3	2.3
	Azerbaijan	6	33.5	5.1	6	0.7	0.6
	Eastern Europe	6	33	5.1	6	0.6	0.6
	Western Europe, America, and Australia	5	18	2.1	3	0.9	0.6
Non-Arab African countries	South Africa	8	40.1	4.1	5	1.0	0.8
	Central and western Africa	7	52.5	4.1	5	1.3	1.1

Tawafa Company	Country	Number of bags	Sample Total Weight (kg)	MCW (t)	XCW (t)	Sample ratio (MCW) (% wt. As received)	Sample ratio (XCW) (% wt. As received)
	Ivory Coast	10	52.9	1.1	2	4.8	2.6
	Kenya	5	19.2	4.1	5	0.5	0.4
Iran	Iran	7	29.75	2.1	3	1.4	1.0
Saudi Arabia Pilgrims	KSA	8	37.5	1.1	2	3.4	1.9
	KSA	8	34	5.1	6	0.7	0.6
	KSA	8	31.5	5.1	6	0.6	0.5
	KSA	8	44	5.1	6	0.9	0.7
	KSA	6	26.5	3.1	4	0.9	0.7
Total		268	1325.6	98.2	127.0	174.1	47.8
The Average		8.4	41.4	3.1	4.0	5.4	1.5

Table A5 The calculated waste composition as a percentage for each camp of the 32 camps

Tawafa company	Camps' pilgrim country	Organic waste %	Plastic %	Paper & cardboard %	Glass %	Aluminium cans %	Cork %	Textile %	Plastic film %	Other metal %	Aluminium foil %
	Sudan	38.1	25.1	17.1	0	0.3	0	15	1.1	3.3	0
	Egypt	29.4	24.6	15.2	0	0	6.6	0	12.8	11.4	0
	Somalia	27.4	3.6	18.5	13.7	5.3	7.9	11.1	0	0	12.5
	Lebanon	27.2	10.7	20.5	11.8	5.9	0	15.8	0	0	8.1
	Algeria	36.2	18.9	13.6	8.3	1.5	0.0	17.3	0.0	0.0	4.2
	Tunisia	42.1	11.4	22.5	0.0	6.5	0.0	4.9	5.8	0.0	6.8
	Syria	44.4	6.6	11.2	0.0	7.7	0.0	9.6	6.2	0.0	14.4
	Kuwait	30.7	18.2	27.3	0.0	5.7	0.0	0.0	18.2	0.0	0.0
	Oman	26.8	20.1	13.1	10.8	4.6	0.0	0.0	7.2	0.0	17.3
Arabian	Qatar	14.7	17.7	31.1	0.0	19.3	0.0	9.8	7.4	0.0	0.0
Countries	Palestine	26.8	25.9	16.6	0.0	5.9	0.0	20.3	4.6	0.0	0.0

Tawafa company	Camps' pilgrim country	Organic waste %	Plastic %	Paper & cardboard %	Glass %	Aluminium cans %	Cork %	Textile %	Plastic film %	Other metal %	Aluminium foil %
	Iraq	21.0	25.5	43.2	0.0	0.0	0.0	4.0	6.4	0.0	0.0
South East Asian	Indonesia	24.1	12.0	20.1	0.0	6.2	0.0	16.2	7.4	0.0	13.9
	Singapore	27.7	28.2	19.3	0.0	6.5	0.0	2.6	2.9	0.0	12.8
	Malaysia	31.5	26.4	27.9	0.0	0.0	7.6	0.0	6.6	0.0	0.0
South Asian	India	32.7	20.4	30.6	0.0	10.2	0.0	0.0	6.1	0.0	0.0
	Emirates	32.8	0.0	20.9	0.0	0.0	0.0	0.0	23.9	22.4	0.0
	Pakistan	31.3	39.8	15.2	0.0	13.7	0.0	0.0	0.0	0.0	0.0
Turkey and Muslims of Europe, Americas and Australia	Turkey	27.8	13.5	18.4	0.0	10.1	0.0	4.5	9.4	0.0	16.4
	Azerbaijan	41.8	11.9	9.0	0.0	0.0	0.0	0.0	22.4	0.0	14.9
	Eastern Europe	26.5	4.5	46.2	0.0	1.5	0.0	0.0	10.6	0.0	10.6
	Western Europe, America, and Australia	55.6	28.3	6.7	0.0	0.0	0.0	0.0	9.4	0.0	0.0
Non-Arab African countries	South Africa	23.1	21.2	17.5	20.3	3.7	0.0	0.0	6.2	8.0	0.0
	Central and western Africa	57.1	11.4	14.3	0.0	3.3	0.0	0.0	11.9	0.0	1.9
	Ivory Coast	31.8	35.7	17.6	0.0	7.0	0.0	0.0	7.9	0.0	0.0
	Kenya	30.7	30.7	28.6	0.0	0.0	0.0	0.0	6.3	3.6	0.0
Iran	Iran	31.9	26.9	25.2	0.0	6.7	0.0	0.0	9.2	0.0	0.0
Saudi Arabia Pilgrims	KSA	8.0	24.0	41.3	0.0	9.3	0.0	0.0	17.3	0.0	0.0
	KSA	8.8	20.6	54.4	0.0	5.9	0.0	0.0	10.3	0.0	0.0
	KSA	11.1	6.3	50.8	0.0	14.3	0.0	0.0	17.5	0.0	0.0
	KSA	22.7	19.3	42.0	0.0	4.5	0.0	0.0	11.4	0.0	0.0
	KSA	15.1	26.4	35.8	0.0	9.4	0.0	0.0	13.2	0.0	0.0
Total		**936.9**	**615.8**	**791.7**	**64.9**	**175**	**22.1**	**131.1**	**279.6**	**48.7**	**133.8**
The Average		**29.3**	**19.2**	**24.7**	**2.0**	**5.5**	**0.7**	**4.1**	**8.7**	**1.6**	**4.2**

Table A6 The calculated weight per pilgrim (g.p^{-1}) for each waste component in the 20 camp for MCW

Tawafa company	Camps' pilgrim country	number of pilgrims	Waste weight per pilgrim (g)	Organic waste (g.p^{-1})	Plastic (g.p^{-1})	Paper & cardboard (g.p^{-1})	Glass (g.p^{-1})	Aluminium cans (g.p^{-1})	Cork (g.p^{-1})	Textile (g.p^{-1})	Plastic film (g.p^{-1})	Other metal (g.p^{-1})	Aluminium foil (g.p^{-1})
Arabian Countries	Sudan	3174	346.6	132.0	87.0	59.3	0.0	1.0	0.0	52.0	3.8	11.4	0.0
	Egypt	2600	807.7	237.5	198.7	122.8	0.0	0.0	53.3	0.0	103.4	92.1	0.0
	Somalia	2525	39.6	10.9	1.4	7.3	5.4	2.1	3.1	4.4	0.0	0.0	5.0
	Lebanon	2500	1240.0	337.3	132.7	254.2	146.3	73.2	0.0	195.9	0.0	0.0	100.4
	Algeria	1500	1400.0	506.8	264.6	190.4	116.2	21.0	0.0	242.2	0.0	0.0	58.8
	Tunisia	2875	34.8	14.6	4.0	7.8	0.0	2.3	0.0	1.7	2.0	0.0	2.4
	Syria	2650	415.1	184.3	27.4	46.5	0.0	32.0	0.0	39.8	25.7	0.0	59.8
	Kuwait	2875	1773.9	544.6	322.9	484.3	0.0	101.1	0.0	0.0	322.9	0.0	0.0
	Oman	2500	440.0	117.9	88.4	57.6	47.5	20.2	0.0	0.0	31.7	0.0	76.1
	Palestine	2833	1094.2	293.3	283.4	181.6	0.0	64.6	0.0	222.1	50.3	0.0	0.0
	Iraq	2770	1119.1	235.0	285.4	483.5	0.0	0.0	0.0	44.8	71.6	0.0	0.0
South East Asian	Indonesia	3027	2675.9	644.9	321.1	537.9	0.0	165.9	0.0	433.5	198.0	0.0	372.0
	Singapore	2600	2346.2	649.9	661.6	452.8	0.0	152.5	0.0	61.0	68.0	0.0	300.3
	Malaysia	2500	1640.0	516.6	433.0	457.6	0.0	0.0	124.6	0.0	108.2	0.0	0.0
South Asian	India	5359	205.3	67.1	41.9	62.8	0.0	20.9	0.0	0.0	12.5	0.0	0.0
	Pakistan	4917	630.5	197.3	250.9	95.8	0.0	86.4	0.0	0.0	0.0	0.0	0.0
Non-Arab African countries	South Africa	2328	1761.2	406.8	373.4	308.2	357.5	65.2	0.0	0.0	109.2	140.9	0.0
	Central and western Africa	7000	585.7	334.4	66.8	83.8	0.0	19.3	0.0	0.0	69.7	0.0	11.1
	Ivory Coast	6700	164.2	52.2	58.6	28.9	0.0	11.5	0.0	0.0	13.0	0.0	0.0
	Kenya	3564	1150.4	353.2	353.2	329.0	0.0	0.0	0.0	0.0	72.5	41.4	0.0
Total		**66797.0**	**19870.3**	**5836.7**	**4256.2**	**4252.0**	**673.0**	**839.1**	**181.1**	**1297.5**	**1262.6**	**285.8**	**985.8**
Average		**3340**	**993.5**	**291.8**	**212.8**	**212.6**	**33.6**	**42.0**	**9.1**	**64.9**	**63.1**	**14.3**	**49.3**

Table A7 The calculated weight per pilgrim ($g.p^{-1}$) for each waste component in the 20 camp for XCW

Tawafa company	Camps' pilgrim country	number of pilgrims	Waste weight per pilgrim (g)	Organic waste ($g.p^{-1}$)	Plastic ($g.p^{-1}$)	Paper & cardboard ($g.p^{-1}$)	Glass ($g.p^{-1}$)	Aluminium cans ($g.p^{-1}$)	Cork ($g.p^{-1}$)	Textile ($g.p^{-1}$)	Plastic film ($g.p^{-1}$)	Other metal ($g.p^{-1}$)	Aluminium foil ($g.p^{-1}$)
Arabian Countries	Sudan	3174	630.1	240.0	158.1	107.7	0.0	1.9	0.0	94.5	6.9	20.8	0
	Egypt	2600	1153.8	338.1	282.9	174.8	0.0	0.0	75.9	0.0	147.2	131.1	0
	Somalia	2525	396.0	109.6	14.4	74	54.8	21.2	31.6	44.4	0	0	50
	Lebanon	2500	1600.0	435.2	171.2	328	188.8	94.4	0	252.8	0	0	129.6
	Algeria	1500	2000.0	724	378	272	166	30	0	346	0	0	84
	Tunisia	2875	347.8	147.35	39.9	78.75	0	22.75	0	17.15	20.3	0	23.8
	Syria	2650	754.7	337.4	50.2	85.1	0.0	58.5	0.0	73.0	47.1	0.0	109.4
	Kuwait	2875	2087.0	2118.3	1255.8	1883.7	0.0	393.3	0.0	0.0	1255.8	0.0	0.0
	Oman	2500	800.0	214.4	160.8	104.8	86.4	36.8	0.0	0.0	57.6	0.0	138.4
	Palestine	2833	1411.9	377.9	365.2	234.1	0.0	83.2	0.0	286.2	64.9	0.0	0.0
	Iraq	2770	1444.0	302.4	367.2	622.1	0.0	0.0	0.0	57.6	92.2	0.0	0.0
South East Asian	Indonesia	3027	2973.2	715.8	356.4	597.0	0.0	184.1	0.0	481.1	219.8	0.0	412.8
	Singapore	2600	2692.3	747.9	761.4	521.1	0.0	175.5	0.0	70.2	78.3	0.0	345.6
	Malaysia	2500	2000.0	630.0	528.0	558.0	0.0	0.0	152.0	0.0	132.0	0.0	0.0
South Asian	India	5359	373.2	121.0	75.5	113.2	0.0	37.7	0.0	0.0	22.6	0.0	0.0
	Pakistan	4917	813.5	253.5	322.4	123.1	0.0	111.0	0.0	0.0	0.0	0.0	0.0
Non-Arab African countries	South Africa	2328	2147.8	496.7	455.8	376.3	436.5	79.6	0.0	0.0	133.3	172.0	0.0
	Central and western Africa	7000	714.3	405.4	80.9	101.5	0.0	23.4	0.0	0.0	84.5	0.0	13.5
	Ivory Coast	6700	298.5	95.4	107.1	52.8	0.0	21.0	0.0	0.0	23.7	0.0	0.0
	Kenya	3564	1402.9	429.8	429.8	400.4	0.0	0.0	0.0	0.0	88.2	50.4	0.0
Total		**66797.0**	**26041.2**	**9240.2**	**6361.0**	**6808.5**	**932.5**	**1374.4**	**259.5**	**1723.0**	**2474.4**	**374.3**	**1307.1**
Average		**3340**	**1302.1**	**462.0**	**318.1**	**340.4**	**46.6**	**68.7**	**13.0**	**86.1**	**123.7**	**18.7**	**65.4**

APENDIX B

PILGRIMS' QUESTIONNAIRE'S REGRESSION RESULTS

Table B1 The optional sorting model's parameters estimation (for 'maybe' answer)

Factors	903 forms			816 forms		
	B	Std. Error	p-value	B	Std. Error	p-value
Intercept	-2.647	1.234	0.032	-2.846	1.293	0.028
Countries' indicators						
GDP/capita	0.000	0.000	0.000	0.000	0.000	0.000
EPI	0.032	0.015	0.031	0.032	0.015	0.032
Waste Generation	0.001	0.001	0.236	0.002	0.002	0.173
Level of education						
Post graduate degree	0.060	0.446	0.892	0.035	0.450	0.937
University degree	-0.330	0.363	0.363	-0.298	0.366	0.415
School degree	0.526	0.286	0.066	0.479	0.286	0.095
No Degree	0	.	.	0	.	.
Tawafa Company						
Western Countries	1.497	0.945	0.113	1.519	0.947	0.109
Non-Arab African Countries	1.183	0.947	0.212	1.249	0.972	0.199
Non-Arab Asian	-0.391	0.953	0.682	-0.222	0.990	0.822
Arabian Countries	1.442	0.886	0.104	1.444	0.898	0.108
Saudi Arabia Pilgrims	0	.	.	0	.	.
Q1- Do you eat in your Mina's camp?						
Always + sometimes	0.417	0.332	0.208	0.352	0.333	0.291
Rarely	0	.	.	0	.	.
Q2- From where do you get your food?						
Camp catering	-0.249	0.252	0.324	-0.176	0.257	0.493
Buy it + both	0	.	.	0	.	.
Q3- Did you hear anything about waste sorting and recycling?						
Yes	0.692	0.282	0.014	0.757	0.284	0.008
No	0	.	.	0	.	.
Q4- Having read the definitions, do you think you will be able to sort your solid waste?						
Yes	0.530	0.304	0.081	0.501	0.305	0.101
No	0	.	.	0	.	.
Q5- Do you sort your solid waste at your home in your country?						
Yes	-0.086	0.264	0.744	-0.157	0.268	0.557
No	0	.	.	0	.	.
Q7- Are you satisfied about the level of cleanliness in Mina's steers during the Hajj?						
Unsatisfied	-0.899	0.320	0.005	-0.931	0.336	0.006
Satisfied	0	.	.	0	.	.
Q8- Are you satisfied about the level of cleanliness in your Mina camp during the Hajj?						
Unsatisfied	-0.561	0.308	0.069	-0.498	0.327	0.127
Satisfied	0	.	.	0	.	.

Table B2 The compulsory sorting model's parameters estimation (for 'maybe' answer)

Factors	903 forms			816 forms		
	B	Std. Error	p-value	B	Std. Error	p-value
Intercept	-3.909	1.257	.002	-4.617	1.633	.005
Countries' indicators						
GDP/capita	0.000	0.000	0.010	0.000	0.000	0.006
EPI	0.051	0.018	0.004	0.040	0.021	0.057
Waste Generation	0.001	0.001	0.268	0.003	0.002	0.110
Level of education						
Post graduate degree	1.481	0.452	0.001	1.751	0.519	0.001
University degree	0.569	0.407	0.163	0.723	0.494	0.143
School degree	0.418	0.314	0.184	0.458	0.378	0.226
No Degree	0	.	.	0	.	.
Tawafa Company						
Western Countries	-1.022	0.850	0.229	0.127	1.045	0.903
Non-Arab African Countries	0.530	0.762	0.487	1.687	1.054	0.109
Non-Arab Asian	-1.672	0.799	0.036	-0.424	1.121	0.706
Arabian Countries	0.266	0.709	0.708	1.023	0.941	0.277
Saudi Arabia Pilgrims	0	.	.	0	.	.
Q1- Do you eat in your Mina's camp?						
Always + sometimes	0.870	0.354	0.014	0.695	0.391	0.076
Rarely	0	.	.	0	.	.
Q2- From where do you get your food?						
Camp catering	-1.293	0.277	0.000	-1.314	0.345	0.000
Buy it + both	0	.	.	0	.	.
Q3- Did you hear anything about waste sorting and recycling?						
Yes	0.161	0.296	0.585	0.527	0.355	0.138
No	0	.	.	0	.	.
Q4- Having read the definitions, do you think you will be able to sort your solid waste?						
Yes	0.421	0.318	0.186	-0.256	0.384	0.504
No	0	.	.	0	.	.
Q5- Do you sort your solid waste at your home in your country?						
Yes	0.595	0.291	0.041	0.714	0.353	0.043
No	0	.	.	0	.	.
Q7- Are you satisfied about the level of cleanliness in Mina's steers during the Hajj?						
Unsatisfied	0.110	0.336	0.742	-0.011	0.419	0.979
Satisfied	0	.	.	0	.	.
Q8- Are you satisfied about the level of cleanliness in your Mina camp during the Hajj?						
Unsatisfied	-0.191	0.325	0.557	-0.273	0.414	0.510
Satisfied	0	.	.	0	.	.