IMPROVING WASTE MANAGEMENT SYSTEMS USING STUDENT-LED ACTIVITIES: A CASE STUDY FOR AN INTERNATIONAL AIRPORT

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SUMMARY: Collaboration between universities and external organisations offers opportunities for multiple and mutual benefits. In this case study we examine a novel coursework task that challenges students to consider and evaluate waste management in a local airport with the intention that the work thus produced sets a possible agenda for the airport to enhance its waste management performance. The students were presented with a "real world" task enriched by context and potential applications whilst the airport benefited from the information generated and the menu of recommendations that was produced. Focusing on airside (aeroplanes and related operations) and landside (air terminal and office) operations, the students' work highlights the need for and opportunities to provide systems and facilities that are appropriate to this task. Waste audits demonstrated a range of opportunities for improving recycling rates, notably in relation to signage and management of food waste. The mutual benefits of this collaborative venture were demonstrated via: i) the airport's uptake of students' recommendations and desire to participate in a follow-up activity ii) positive feedback from the airport and students and iii) the quality of the exercise as a vehicle for academic learning and development of professional and employability skills. Approaches to education in waste and resource management incorporating collaborative work of this nature are strongly recommended.

1. INTRODUCTION

Academics at the University of Southampton's International Centre for Environmental Science have a long history of initiating, developing, organizing and delivering waste-focused activities that involve collaboration with university students and external organisations. The aims of these activities include:

- The generation of new knowledge and case studies that highlight the strategic and practical implications and impacts of waste-related research locally, nationally and internationally;
- Provision of real-world experiences for students to enhance their problem-solving, sustainability, team-working, consultancy and employability skills;
- Provision of mutual benefits to external organisations, universities and students, including sharing of limited resources to extend their value and impact.

The activities have typically involved students working on module-based assignments, internships, work placements and dissertations. A diverse range of endeavours has centred around: i) improving waste collection and recycling systems, ii) waste prevention, and iii) enabling reuse and recycling. This paper outlines the educational approach taken and results achieved when under- and post-graduate students were tasked with working with a nearby airport to undertake a waste audit with the aim of identifying actions that could subsequently improve the airport's waste management systems and operations.

1.1 Aviation

Civil aviation is a global industry and its challenges are global in scale. The industry has grown spectacularly: since 1970, air traffic has doubled approximately every 15 years. In 2012, the global aviation industry provided 57 million jobs and $2.2 trillion in economic activity. Aviation is predicted 5% annual growth to 2030, resulting in projections of 5.9 billion passengers, ~150 million tonnes of cargo, 82 million jobs and $6.9 trillion of global Gross Domestic Product (Grote *et al*, 2014). Aviation sustains around a million jobs in the United Kingdom (UK) while supporting a host of other economic sectors (AOA, 2014). As a result, civil aviation is a significant contributor to greenhouse gas emissions and waste arisings and these impacts will continue to rise in the future (Pitt & Smith, 2003; Grote *et al*, 2014).

Parameshwar (2011) identified seven sources/types of solid waste in airports: Municipal Solid Waste, Industrial Waste, Hazardous Waste, Hospital Waste, Construction and Demolition Waste, Waste Electrical and Electronic Equipment (WEEE) and Agricultural Waste. Many of these waste types require specialist collection and disposal, adding to the challenges of waste management at airports. Airports can produce waste in equivalent volumes to small cities, so the management of this waste can be a large and complex task. Environmental issues are argued to be the greatest challenge faced by the air transport industry in the EU and should be given high priority (Muliasari, 2010, cited in Sondakh et al., 2014). Despite this situation, solid waste management at airports has often been overlooked in favour of focusing on air and noise pollution (Carra et al., 2013).

Studies of commercial airports' municipal solid waste suggest 40% of deplaned waste could be recycled (FAA, 2013). Addressing deplaned waste involves communication between many stakeholders and airports have an important role working with airlines to provide recycling facilities. The Federal Aviation Administration (2013) has highlighted cases where source-separated recyclable material has been put into non-recyclable waste streams due lack of communication and inadequate facilities. Other issues that reduce the quantity of recyclable materials include mis-sorting and contamination; these issues also increase reprocessing costs and reduce the quality of materials (WRAP, 2015).

1.2 Study location and characteristics

Southampton International Airport Limited (SIAL) is located in Hampshire, UK, to the north east of the City of Southampton in Eastleigh. SIAL handled 40,374 flights and 1,829,575 passengers in 2014. The airport is currently owned by AGS Airports Ltd., which is a partnership between Ferrovial and Macquarie Infrastructure and Real Assets (MIRA) established in 2014. SIAL is the UK's 18th biggest airport based on passenger numbers (AOA, 2014). Due to its catchment area, SIAL's passenger numbers are forecasted to increase from around 1.84 million in 2005 to 5 million in 2030 (Southampton Airport, 2006).

Table 1 shows the tenants that operate at the airport. The airport is a base for Flybe and KLM airlines, and hosts several other companies such as car rental businesses, retail, and support services. This range of on-site activities means that waste management is a complex issue. SIAL has a Corporate Social Responsibility policy to manage the business in a way which takes into account their associated economic, social and environmental impacts. As well as committing to managing their environmental impacts, SIAL commit to encouraging recycling and striving to keep waste to a minimum. SIAL's waste strategy is based on three core principles: "best practicable environmental option", the waste hierarchy and the proximity principle.

The implementation of recycling schemes in some US airlines has led to cost savings (Nelms, 1993), suggesting that a more efficient strategy could save SIAL money. Smaller-scale airports are likely to be more sustainable than larger ones, particularly in terms of waste management. SIAL, as a smaller airport, should have scope to become more sustainable.

Table 1. Tenants and their operating sector found on the site of Southampton Airport.

Tenants	*Type*
Southampton International Airport Ltd (SIAL)	Airport Operator
Flybe	Airline
Swissport	Ground Handling
Menzies	Ground Support
TRG	Catering
WH Smith	Retail
World Duty Free	Retail
Moneycorp	Retail
Costa Coffee	Catering
The Globe Bar and Kitchen	Catering
The Olive Tree	Catering
Exxon Mobil	Fuel
APCOA	Car Park Management
AVIS, Enterprise, Hertz, Europcar	Car Hire

Waste from the airport arises from both landside and airside operations. SIAL employs the contractor Veolia to dispose of general waste, recyclable waste and hazardous waste. In public areas there are two types of clearly labelled bins; one for general waste and one for recyclable materials. There are chewing gun recycling bins in selected locations. Hazardous waste, including sharps, lighters and matches, flammable liquids and other liquids are collected separately, often as passengers pass through security points. Waste electrical and electronic equipment (WEEE), scrap metal, confidential waste, printer cartridges and glass are also collected separately on-site. After bin collection, the waste is compacted on-site. Recyclable waste is collected from Southampton airport via a co-mingled sorting system, where all recyclables are mixed together, and sorted into different types of recyclable materials in Veolia's nearby Materials Recovery Facility (MRF). The waste is collected on a pay by weight contract and on demand. General waste is not landfilled but incinerated to produce energy.

In 2015, SIAL was charged £13 per tonne for recycling and £93 per tonne for general waste removed from the site by Veolia. The transport costs for removing the waste was £103 per waste vehicle journey. SIAL provided data on the annual mass of recycling and general waste. Table 2 shows the estimated annual costs associated with the removal of waste at the airport.

Table 2. Annual waste generated by Southampton Airport based on data acquired from SIAL for 2014. Annual transport trips were calculated using the assumption that a 26 tonnes waste disposal vehicle was used (Somerset Waste Partnership, 2015).

	Mass (tonnes/annum)	*Cost to dispose (£/tonne)*	*Annual transport trips needed (n)*	*Annual cost of trips (£)*	*Total cost (£/annum)*
General Waste	554	93	22	2266	53,779
Recycling Waste	318	13	13	1339	5477
Total	872	-	35	3605	59,256

2. METHODOLOGY

2.1 Students' Task

The task was set as part of a suite of assessments for the University of Southampton's module in "Sustainable Resource Management". This is an optional module available to students in the final year of a Bachelor's (BSc) degree and to students studying at Masters (MSc) level; these students are studying at levels 6 and 7, respectively, within the UK's Frameworks for Higher Education Qualifications (QAA, 2014). Students undertaking a waste-focused module were divided into two groups (air- and land-side wastes) representing waste generated by planes and their operations (air-side) and by commercial operations and the public whilst waiting to collect passengers or to depart airports (land-side) in order to undertake on-site audits. SIAL provided a representative sample of collected air- and land-side wastes, divided into "recyclables" and "non-recyclables" as collected. The students were given an opportunity to talk to SIAL representatives and ask questions. The students worked with tutors to devise an audit methodology, including equipment list, schedule and risk assessment. They shared data and were bound by normal obligations associated with professional consultancy projects. Their task was to interrogate the data set and produce a report that provided:

- A step-by-step overview of the waste audit methodology used and any assumptions made.
- An overview of the waste arisings for the air- and land-sides of SIAL, supported by appropriate tables of information and photographs.
- An estimate of annual waste arisings by waste category and location, benchmarked using authoritative secondary data.
- An evaluation of the waste arisings for the air- and land-sides of SIAL, highlighting any issues e.g. contamination; mis-sorting; potential for quantitative reduction by waste category; potential for system improvements; potential for cost reduction, income generation, opportunities for developing potential circular economy projects (by material), etc.
- A list of *ca.* three to five potential improvement projects, ranked by likely benefit.
- A summary of how their findings could contribute to the improvement of the current waste management system employed by SIAL.

2.2 Waste Audits

2.2.1 Approach

Two waste audits were conducted at Southampton Airport on the 19th October and 16th November 2015 using a sample of the waste disposed in general and recycling bins collected at the airport the previous day. Waste generated from tenants, placed into the general and recycling bins was also included. General waste and recycling arising from landside and airside operations was audited separately (using the same methodology) giving four separate waste fractions; airside general waste, airside recyclables, landside general waste and landside recyclables. Two audits were completed to give a more reliable representation of the waste generated.

The audits were carried out in secure, demarcated areas that were clearly signposted to the public and airport/tenant employees to ensure adherence to health and safety rules. A health and safety briefing was provided by an academic in class prior to the audit and on the audit day by a member of the airport's staff. Large disposable plastic sheets secured with tape were used to cover the ground to avoid contamination and spillage. Sorting tables were covered in disposable plastic. All students were required to wear disposable plastic gloves throughout the audit, and long-sleeved clothes and trousers were required to avoid skin contact with sharps and wastes. Suitable footwear with sufficient grip was required to protect the foot from falling objects and prevent slipping. Ingestion of any waste was strictly not permitted. High visibility jackets were worn throughout the duration of the audit. Antibacterial wipes were provided to clean hands as necessary and at the end of the audit.

Waste to be sorted was assembled in moveable cages prior to the audits. Each bag of recyclables and non-recyclable waste streams was labelled and weighed using luggage scales before being opened. One bag of waste at a time was spread over the plastic sheet or on a covered table and physically separated into selected categories using plastic tongs. Liquids were disposed of into a separate bin. For each group, materials were separated into the following general categories; paper, cardboard, metal, plastic, glass, putrescible/organic, textiles, rubber, wood, sanitary and other. These categories were then subdivided (by the students) into more specific categories to classify further the waste types (see Appendix 1). The weight of each sub-category was recorded on pre-prepared audit forms.

The annual total weight of general waste and recyclables from both landside and airside operations was calculated by multiplying the mass recorded from the two audits by 365, the number of days the airport operates. The same method was used to calculate the annual total weight arising from the main waste categories and sub categories. It should be noted the annual weight of waste does not include hazardous waste, WEEE or confidential waste. The percentages of each waste category were calculated for all four groups by adding the weight of each waste category from both audits together and dividing by the total weight of waste. Similarly, the recycling rate was calculated by dividing the weight of recyclable materials by the total weight of waste.

The segregated materials were placed in empty plastic bags and after all the waste had been categorised, the separate bags were again weighed using luggage scales. Throughout the audit, photographs were taken as a visual record of the waste samples, highlighting miscellaneous items or frequently occurring wastes. It was paramount to ensure the complete separation of recyclables and general waste throughout the audit. Following the audit, the segregated bags of waste were sorted into recyclables and general waste and collected by SIAL's waste contractors for normal disposal and treatment.

2.2.2 Assumptions

In pre- and post-audit workshops, the students discussed and agreed on a number of assumptions that were pertinent during data analysis and interpretation:

1. The data for general waste arising from landside operations was not available for the second audit on the 16th November 2015. It emerged during a tutor-led discussion that one of the students (who did not own up) lost the data sheet upon which these data were recorded. The students agreed to analyse photographs taken of the general waste during the 16th

November activities in order to ensure that data collected for landside general waste was consistent with that from the first audit. Post analysis, it was agreed that the quantities for landside general waste should be doubled to make them comparable.
2. To calculate the annual waste arisings at Southampton Airport, it was assumed that i) the mass of waste from the audits was representative of a day's waste generation on site and ii) there is little variation in waste arisings all days of the week and all times of the year.
3. Although different students undertook the two audits, it was assumed that all waste was separated into the same categories in both audits to allow for comparability.

3. RESULTS

In this section, examples of some of the key results provided by a "typical student" are presented in order to illustrate the work undertaken. The figures produced by the student are presented unedited, although tables have been edited to suit the required format for this paper. Photographs of the audits in progress are shown in Plate 1. The results have been benchmarked with the literature and by SIAL and we estimate that they are probably accurate to an order of magnitude level.

3.1 Waste arisings

The total waste generated in the SIAL audits is shown in Table 3. The total estimated annual waste at SIAL is shown in Table 4. There is a large difference between the estimated annual waste produced from the student audits and the estimates produced by SIAL. This student's values under-estimated the weight of waste produced by the airport by approximately 87% and this was typical. As an explanation, the students typically suggested that the quantities of waste audited were not representative of a usual day at the airport. In fact, every student neglected to recognise that they were given a sample of the daily waste collected, and therefore needed to multiply by a daily scaling factor as well as an annual scaling factor. However, the percentages of general waste (65%) compared with recyclable waste (35%) from the audit was similar to that supplied by SIAL; the proportions are, of course, unaffected by scaling.

Table 3. Estimated weights of waste from the two audits at Southampton Airport.

	General Waste (kg)	*Recycling (kg)*	*Total (kg)*
Airside	111.8	48.2	160
Landside	101.3	65.1	166.4
Total	213.1	113.3	326.4

Table 4. Estimated annual weight (tonnes) of waste produced at Southampton Airport.

	General Waste	*Recycling*	*Total*
Airside	40.7	17.5	58.2
Landside	36.9	23.7	60.6
Total	77.6	41.2	118.8

Plate 1. Photographs of the waste audits in progress at Southampton Airport. **A** Students undertaking the waste audit; **B** A selection of avoidable food waste found during the SIAL waste audits; **C** A disposed-of in-date uneaten meal (avoidable food waste).

In terms of benchmarking, based on Pitt and Smith's (2003) UK airports study, SIAL had a comparable level of waste per passenger with Edinburgh Airport, both of which belonged to BAA at the time of the study. Pitt and Smith (2003) reported that for 2000-2001 SIAL had the second lowest reported waste per passenger (0.23 kg/passenger), above Edinburgh Airport (0.21 kg/passenger) and below Aberdeen (0.26 kg/passenger). There are no more publically available data on airport waste generation so it was not possible to benchmark SIAL against current performance at other UK airports. A study of various international airports reported a range of recycling rates from 13% (Atatürk) to 83% (Frankfurt) (Kilkiş and Kilkiş 2015).

3.2 Airside Waste

The waste-by-category proportioned by weight for airside general waste (estimated by the students; Figure 1) showed that organic waste and contaminated packaging contributed the largest proportion (28%) of general waste. Food waste constituted 45% of this category, with contaminated packaging responsible for the remaining 55%. Food waste comprised 89% avoidable and 11% unavoidable items (Lebersorger & Schneider, 2011). Contaminated plastic contributed most by weight to the contaminated packaging category. Liquids and paper each comprised 25% of the general waste. The paper category comprised mainly newspaper (40%) with 21% mixed paper and 17% empty waxed paper cups. Plastic accounted for 11% of the general waste total; 85% of the plastic was high grade or recyclable plastic and 15% low grade plastic. Other categories accounted for minor proportions of the general airside waste.

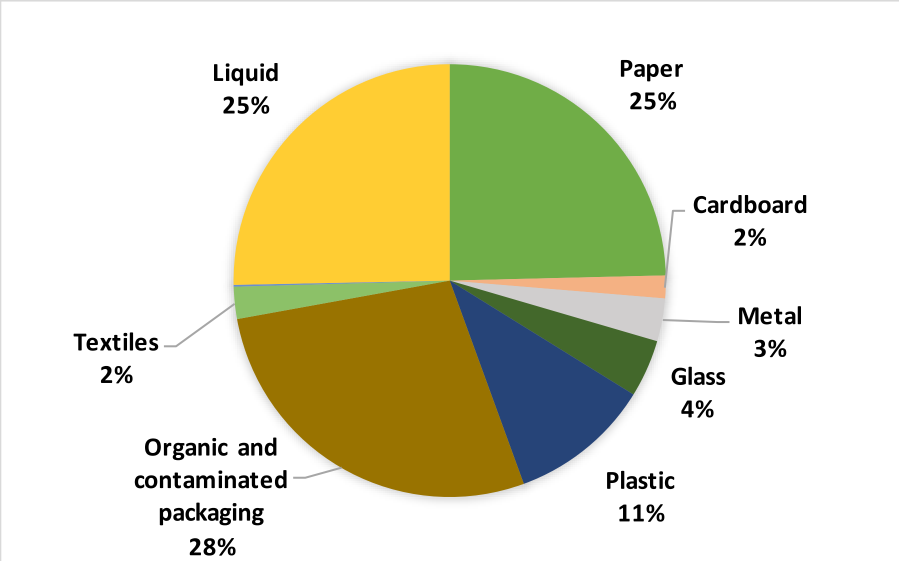

Figure 1. The waste-by-category proportioned by weight for airside general waste from both audits at Southampton Airport.

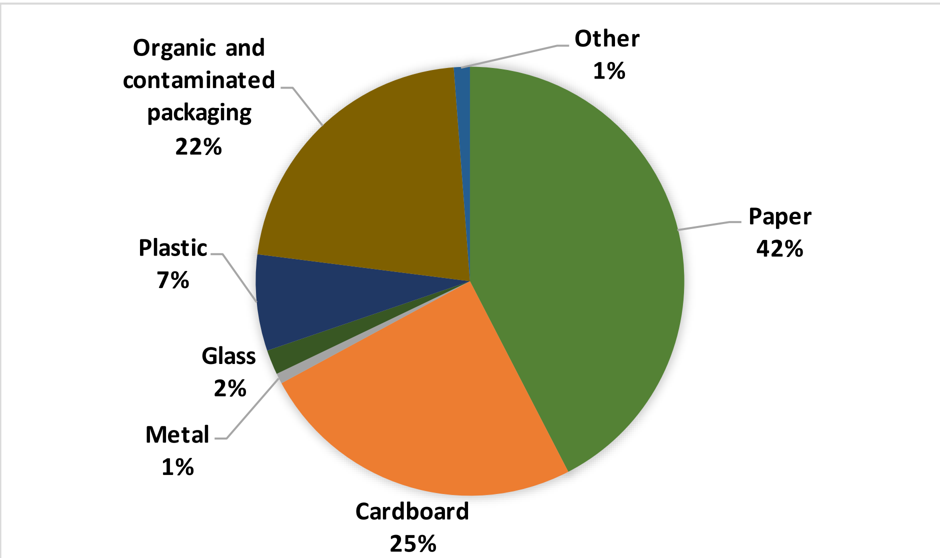

Figure 2. The waste-by-category proportioned by weight for airside recyclable waste from both audits at Southampton Airport.

The waste-by-category proportioned by weight for airside recycling (Figure 2) showed that paper accounted for the highest proportion of recyclable waste (42%). Paper consisted mainly of magazines and printed materials (64%), newspapers (22%) and empty waxed paper cups (10%). Cardboard was the second most abundant waste by weight, comprising 25% of the total. Organic and contaminated packaging accounted for 22% of the total airside recycling waste, with food waste making up 18% and contaminated packaging 82% of this total. The food waste comprised 70% avoidable and 30% unavoidable items by weight. Contaminated paper and card contributed to the majority of the contaminated packaging category. Plastic accounted for 7% of the total recycling mass with 81% deemed high grade and 19% low grade or non-recyclable plastic. Other materials were recorded in relatively low quantities.

3.3 Landside waste

The waste-by-category proportioned by weight for landside general waste (Figure 3) showed that organic and contaminated packaging contributed the highest proportion of landside general waste (71%). Food waste accounted for 81% of the organic waste and contaminated packaging fraction, and contaminated packaging made up the remaining 19%. The food waste fraction comprised 65% avoidable and 35% unavoidable items. The contaminated packaging consisted of equal proportions of contaminated plastic and contaminated paper/card.

Paper accounted for 16% of general waste. The most common paper waste type was empty waxed paper cups which with accounted for 43% of all paper waste. The second most abundant was mixed paper at 39% followed by newspapers at 10%. Plastic accounted for 8% with high grade plastic making up 61%. Cardboard, glass and metal accounted for the remainder (5%) of general landside waste.

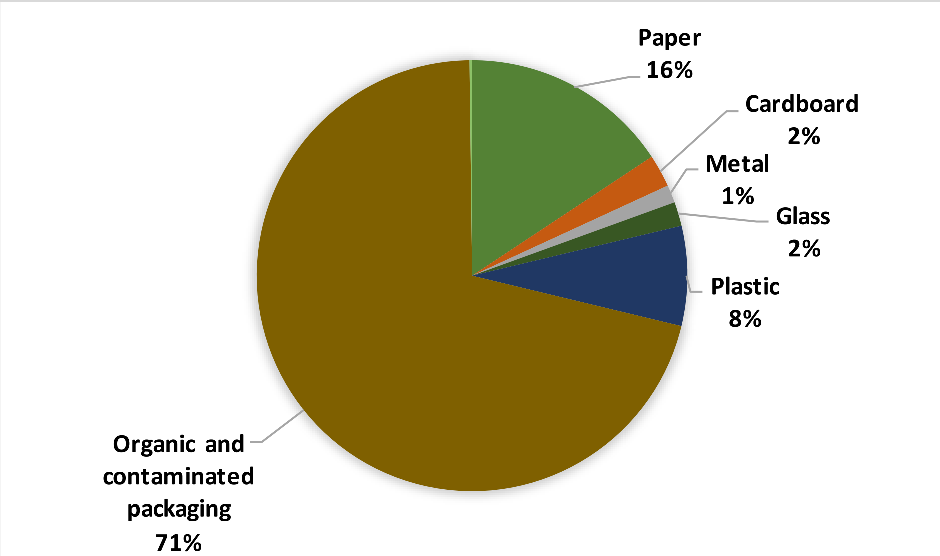

Figure 3. The waste-by-category proportioned by weight for landside general waste from both audits at Southampton Airport.

The waste by category proportioned by weight for landside recyclables (Figure 4) showed cardboard constituted the highest proportion of landside recyclables (42%) with paper the second most abundant material (26%). Office paper made up the highest percentage (37%) of the paper category and newspapers comprised 30%. Organic and contaminated packaging accounted for 25% of the total recyclable waste and food waste accounted for 8%. Unavoidable food waste made up 89% of the total food waste. Contaminated packaging comprised 92% of organic and contaminated packaging waste category; similar weights of contaminated plastic and contaminated paper/card were collected. Plastic accounted for 6% of the total with high grade plastic making up 61% of total plastics. Metals accounted for 1% of the total landside recyclable waste sampled.

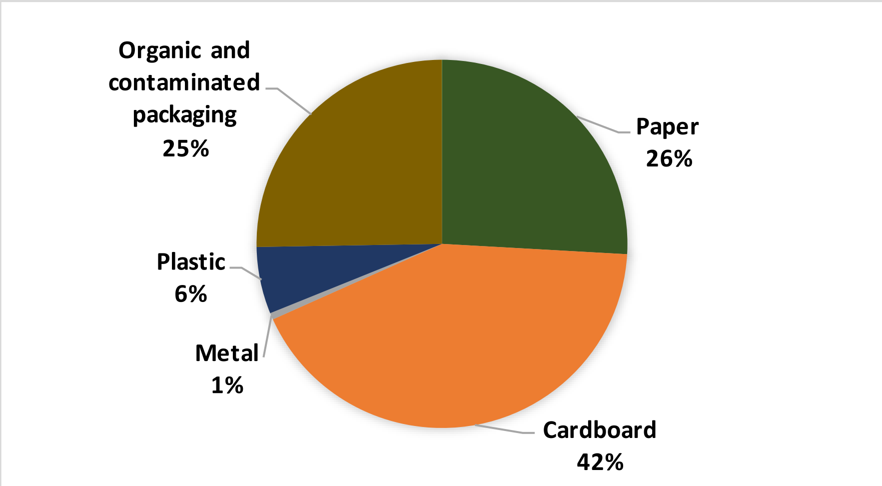

Figure 4. The waste-by-category proportioned by weight for landside recyclable waste from both audits at Southampton Airport.

4. DISCUSSION

4.1 Airside waste arisings

The quantity of avoidable food waste is notable in both general waste and recyclable bins. Figure 5 highlights the difference in quantities of avoidable and unavoidable food waste in the four fractions collected and audited. Airside general waste has the largest percentage of avoidable food waste. Plate 1 shows a selection of the avoidable food waste found during the audits including sandwiches still in packaging, full bottles of drink and snacks. To improve the system, SIAL should encourage the reduction of avoidable food waste quantities, especially in the onsite catering outlets. The presence of both avoidable food waste and unavoidable food waste needs to be removed from recycling bins to reduce contamination and increase recycling rates. Having separate food waste bins should be considered to reduce the contamination and associated costs.

Paper in general waste could be diverted into recycling bins. It was noted that newspapers made up a higher majority of paper in airside general waste compared to landside, hence suggesting that recycling bins on the airside are not being utilised properly for newspapers. This may be affected by waste arising from passengers on aircrafts. When collecting waste from passengers on board planes, staff could be provided with a container to collect paper including newspapers. Recycling bins could also be labelled more effectively by SIAL in public areas so the public are informed where to put paper, and what forms of paper can be recycled.

The majority of cardboard from airside operations is being recycled with only 2% found in general waste. The majority of cardboard was large boxes from suppliers, suggesting that airport and tenant staff are aware of and implementing the recycling process for cardboard.

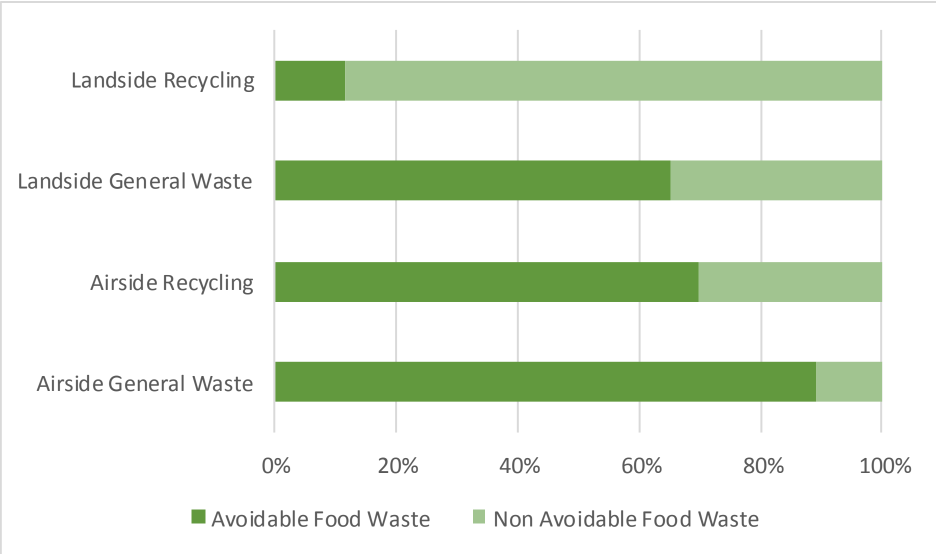

Figure 5. Proportions by weight of avoidable and unavoidable food waste from the four waste groups from both audits at Southampton Airport.

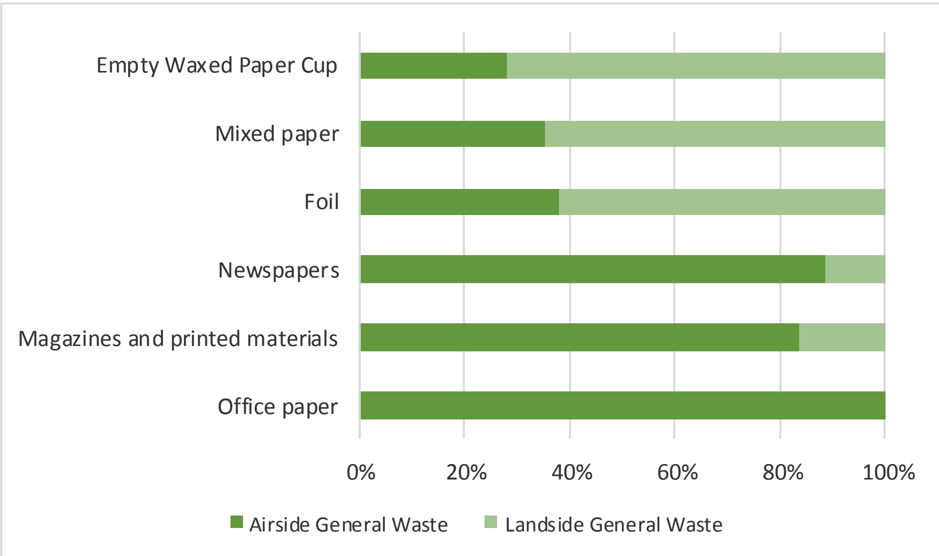

Figure 6. Proportions by weight of sub categories of paper found in airside and landside general waste bins from both audits at Southampton Airport.

4.2 Landside waste arisings

The proportion of food waste and contaminated packaging was higher for landside operations than airside. This is to be expected due to the higher quantity of restaurants and shops selling food on the landside area. Organic and contaminated packing waste accounted for high percentages of waste in both air- and land-side general waste and recycling. The need to throw away plastic bottles at security checkpoints on the landside contributed to the quantity of contaminated plastic in both recycling and general waste bins as many of these bottles were not empty. The need to reduce the paper in general waste bins and to ensure its placement into recycling bins is apparent. There was a high quantity of empty waxed paper cups in general waste and so ensuring these are placed into recycling bins is vital in reducing the amount of paper found in general waste. There was a much higher proportion of newspapers in recyclable than in general waste, which suggests the public are recycling newspapers better in landside areas than in airside areas. The high quantity of cardboard in recyclable bins again suggests staff use the recycling system for cardboard correctly. There appears to be mis-placement of plastics with a high percentage of high grade recyclable plastics in the general waste bin and also with low grade non-recyclable plastic in the recyclable bin. This observation suggests the public are not aware which plastic items can be recycled.

Based on the samples audited, the recycling rate for airside waste was calculated as 30% and for landside as 39%; the overall recycling rate for the airport was estimated to be 35%. There is clearly scope for improvement and hence potential for cost and efficiency savings.

4.3 Improvements to the airport's operations and systems

The students offered a range of suggestions that could assist Southampton Airport to improve its waste management practices. To illustrate the ideas generated by students, sections 4.3.1-4.3.7 show verbatim examples – including assumptions, costings, cited references, grammatical and some other minor errors - of what was suggested in the coursework reports submitted.

4.3.1 Reducing mis-sorting

The audit showed that mis-sorting between general waste and recycling bins was high. It was concluded that 47.9kg (42.8%) of airside general waste was wrongly classified and instead should have been recycled. For landside it was found that 25kg (24.6%) of waste was mis-sorted, giving a total general waste mis-sort rate of 44.9%. Using SIAL's annual general waste data and the respective costs for disposing of waste means the airport could transfer 248.7 tonnes of general waste into recycling waste and hence **save £19,896 a year**.

To reduce mis-sorting errors, the airport needs to clearly indicate what should and should not go into each bin. The airport users have travelled from different areas of the country and their understanding of recycling will not always be the same as that offered by the airport. (Noehammer and Byer, 1997). It is therefore essential the bins at Southampton Airport are clearly labelled to indicate what can be recycled to increase the recycling rate and to reduce contamination of recycling bins. Currently the labels on the bins are not at eye level meaning that they are less likely to be read. Having labels and pictures on the walls above the bins showing where items, such as paper cups, should be placed will allow the public to be more informed. Examples of clear signs have been produced by Hunt Office (2015).

The types of bins used can also help to improve recycling rates. The audit noted there were higher quantities of high grade plastics, often in the form of plastic bottles, in both airside and landside general waste bins. The restriction on liquids passing through security at airports means that personal drink bottles are not permitted. As a result there is a large quantity of plastic bottles being thrown away at the landside terminal, especially in the security area. Ensuring all plastic bottles are recycled will reduce the general waste quantities of plastic. Having novelty recycling bins such as the one designed by Bin Shop (2015) (Figure 13) encourages the public to recycle their plastic bottles and would be effective if placed near the security section of the airport.

4.3.2 Food waste

Putrescible/organic waste made up a large proportion of the residual and recyclable waste arisings at SIAL. This category is made up of food waste and contaminated packaging (over ¼ full of putrescible/organic material). Food waste can be broken down into avoidable, possibly avoidable and unavoidable categories, and contaminated plastic, paper/card, waxed paper cups and other contaminated packaging. Food waste is a major issue, with 8.3 million tonnes (22% of food purchased) disposed of in the UK in 2012 (WRAP, 2012). Around half of this waste is classed as 'avoidable'; food that would have been edible but was generally thrown away because it went past it's use-by date without being eaten (WRAP, 2012).

To properly deal with collected food waste it is important to separate it. Food waste and contaminated packaging in recycling bins reduces recycling rates and should be avoided, while contaminated packaging placed in general waste bins has the possibility to be recycled if the food waste is removed. Having a separate food waste bin would reduce the amount of contaminated packaging and food waste in recycling bins, while allowing more material to be recycled from general waste bins.

A case study at London Stanstead Airport (LSA) is informative. LSA is larger than SIA, servicing 18 million passengers and producing 203 tonnes of food waste annually (WRAP n.d.). The airport began a separate food collection project in 2010, working with on-site retailers to design the scheme. Segregating food waste improved rates of recycling and improved the value and hygiene of dry-recyclables due to reduced contamination (WRAP n.d.). The food waste collection service increased recycling rates at the airport from 51% before the scheme to 56% after (LSA, 2014). Whilst small, a 5% increase in recycling rates from food collection alone would be an important step towards improving waste management at SIAL.

A common disposal method for food waste is biofuel production, which can be very beneficial in terms of preventing methane gas production in landfills and replacing fossil fuels as a source of energy and liquid fuel (Girotto *et al*. 2015, Karmee 2016). Common uses of food for energy include incineration, fermentation and anaerobic digestion (Girotto *et al*. 2015). Biofuel production allows low value waste to be made into high value liquid fuel whilst diverting edible feed-stock away from biofuel production (Karmee 2016). In the future, anaerobic digestion may also be implemented to produce higher value products such as lactate, polyhydrxalkanotes and succinate – it's possible that this commodity industry may become so lucrative that operators will buy organic waste such as food for a good price (Clarke and Alibardi 2010).

The airport could also explore the possibility of composting or vermicomposting food waste on-site, reducing economic costs associated with the removal of large quantities of food waste from the airport. The process could involve the decomposition of organic waste either aerobically or anaerobically with vermicomposting involving earthworms to speed up the process (Lim *et al.* 2016). Composting produces less carbon emissions than incineration and landfill, 0.284 t CO_2e/ton compared to 1.287 t CO_2e/ton for landfill (Lou and Nair, 2009) and so is seen as an more environmentally friendly way of dealing with waste (Erses Yay, 2015). In addition the compost made can be used on-site for the grounds maintenance or sold as fertilisers (Wu *et al.* 2014) meaning that a zero waste system can be implemented where a material once thought of as waste can be used to gain value (Curran and Williams, 2012). A study by Cutjaki *et al.* (2012) showed that a 7.12 × 106 kg composting plant had a payback time of 2.9 years if the compost produced can be sold and so the financial benefits of composting are apparent. Composted food waste on site would save **£3464.40 per annum** compared to the costs from disposing of food waste in general waste. However if composting on site is not viable, SIAL should liaise with Veolia to collect food waste separately to be composted at a reduced cost per tonne than that of general waste.

4.3.3 Re-filling schemes

As an alternative to recycling water bottles the airport should consider installing water fountains on the airside of security meaning the public could refill their bottles instead of placing them in the waste bins. This scheme is already used in some UK airports and as prevention is the highest component on the waste hierarchy, it is the most beneficial in the reduction of waste. Although the cost of installing water fountains and the subsequent water usage needs to be taken into account, the savings in the reduction of high grade plastic from general waste and recycling is estimated to save 10,512kg of plastic currently placed in general waste, equating to a saving of £977.60 per annum and 3989.4kg from recycling, saving £51.90 per annum giving a total saving of **£1029.50 per annum.**

4.3.4 Recycling newspapers

It was noted in the audit that newspapers made up the majority of paper placed in airside general waste bins, but this was not the case on the landside where newspapers were commonly recycled. This suggests there is a difference in public accessibility to recycling on the airside. An explanation for this could be due to the fact that on airplanes there is rarely a recycling bin and so newspapers are placed in general waste. SIAL should encourage airlines to promote the need to recycle and should make recycling facilities available on planes. This small behaviour change will reduce the amount of paper in airside general waste bins and hence save the airport money on the cost of disposing general waste. Transferring all newspaper and magazines from airside general waste into recycling could save **£421.30 per annum.**

4.3.5 Reuse schemes

The audit showed that a substantial amount of waxed paper cups accounted for airside and landside waste which can mainly be attributed to Costa coffee. As the drinks cannot be taken through security, it can be assumed they have to be consumed in the landside terminal of the airport. SIAL could liaise with Costa to supply reusable plastic cups which can be taken away from the café but are collected at collection points. The procedure of reusing is higher on the waste hierarchy than the current system of recycling paper cups and so should be encouraged. To encourage users to return cups, a system similar to the recycling system in Germany and some states in the USA could be implemented where a deposit is paid on an item and when it is returned, the deposit is returned to the purchaser. This has been shown to double reusing rates (Campbell *et al.* 2016). This can be reinforced using face to face communication from the staff advising customers where to place empty cups, as face to face communication has been shown to improve recycling rates (Nixon and Saphores, 2009). Preventing waxed paper cups from being disposed could remove 1238.3kg from general waste, saving £115.20 an annum and £12.63 from recyclables, giving a total saving of **£127.80 per annum.**

4.3.6 Reducing liquids

Effort should be made to reduce liquid contamination by targeting Costa and airlines as they produce the largest quantities of contaminated materials. This can be achieved by providing somewhere to pour away liquids near Costa separate to recyclable waste streams (FAA, 2013), this should also occur at airport security to obtain un-contaminated high grade plastic bottles as no liquids more than 100ml can pass through (UK Government, 2015).

4.3.7 Innovative opportunities for developing potential circular economy projects

In a circular economy (CE) large volumes of finite resources are captured and reused (Huber, 2000), bringing benefits for the environment and economy (Goodwin, 2015). This can occur within the airport itself and between the airport and other industries as they use the materials the airport regards as waste and vice versa. In this way the 'waste' from one industry is used as a resource for others (Frosch and Gallopoulos, 1989), leading to a system based on multiple closed loops with little waste disposed by landfill or incineration (Hawken, 1994).

The CE can be implemented by the principle of 'cradle to cradle' production, focusing on the need to redesign products. This includes products that are designed for reuse and ones that can biodegrade to fertiliser at the end of life (Preston, 2012). These products made from plant-based materials with no hazardous chemicals include the example of furniture made from Elephant grass at Amsterdam Airport; this idea could be developed at SIAL.

Products that have been designed for a cycle of disassembly and reuse can be leased or rented to the consumer; in this way it is in the manufacturers interest to reuse the materials and create a durable product to keep it in use for as long as possible (Ellen MacArthur Foundation (EMF), n.d.). Leasing materials and products such as electrical goods, furniture, and vehicles can occur at SIAL. Schiphol Airport has a future plan to focus on usage of products instead of ownership. 'Light as a service' and 'leasing lumens' is an example being developed by Philips planned for Amsterdam Airport Schiphol that could also be considered at SIAL. This is represented in figure ten as 'the power of circling longer'. This refers to maximising the number of consecutive cycles and the time in each cycle. Each prolonged cycle avoids the material, energy and labour of creating a new product or component (EMF, 2014).

The 'power of cascaded uses across industries' represents materials that have diverse reuse activities. This can occur for materials disposed by SIAL including textiles (upholstery), paper, card, and plastics. For example, before cotton fibres are returned to the biosphere, the cotton in chair upholstery can be reused as fibre-fill in furniture, this fibre-fill can later be reused in stone wool insulation for construction (EMF, 2014).

At SIAL decreased contamination should occur for all recyclables including paper, card, glass, plastics, food and organics so recycling and reuse can increase, as contaminated items are disposed of as non-recyclables. 'The power of the inner circle' refers to changes that are made to products before reuse. The tighter the circle the less a product has to be changed. Savings of labour, energy and value in the product -and externalities (greenhouse gas emissions, water and toxicity) - increase when fewer alterations are required (EMF, 2014). At SIAL this applies to electrical goods and furniture; SIAL should use products that have been designed for durability, easy reuse and disassembly.

Through the 'Europe 2020 Strategy' for increased resource efficiency the Green Alliance proposes a 'recovery reward' for UK metals, this will increase resource recovery and could benefit organisations like SIAL as an 'urban mine' of resources (Ongondo *et al.*, 2015). Demand will overtake reserves for critical metals, the UK is dependent on imports, and therefor resource security is low. Recycling of platinum-group metals for example, is desirable due to limited supply and difficulties of mining and refining: Ores contain seven parts per million of platinum-group metals and require 20 million tonnes a year to be refined to produce 143 tonnes of purified metals (Frosch & Gallopoulos, 1989). Platinum group metals can be reused from catalytic converters in vehicles, the airport should work with car hire companies such as AVIS, Enterprise, Hertz, and Europcar to encourage the materials from the vehicles to be recovered at end of life.

Essential components of electrical and electronic equipment (EEE) include critical metals: a group of metals that experience "demanding supply risks and economical relevance despite low metal volumes" (Bakas *et al.*, 2014, pg. 23). They include precious metals (gold, silver, and palladium) and special metals (indium, selenium, tellurium, tantalum, bismuth, antimony) (Bakas *et al.*, 2014) making them a rich source of valuable resources (Oguchi *et al.*, 2011; Ongondo *et al.*, 2011). All metals and EEE at SIAL should be recycled; EEE should be designed so the metals contained can be easily extracted. One of the main issues that prevent waste electronic and electrical equipment (WEEE) recycling are bad collection methods, therefore SIAL should take responsibility to segregate WEEE and metal from non-recyclable waste steams (Bakas *et al.*, 2014).

Brunton (2014), a consultant from 'Vegware' highlights that you can't compost food with plastic contamination, and vice versa. Vegware makes compostable catering disposables from biodegradable material, unlike most food packaging; this can be recycled with food waste. Compostable packaging is in use at the Royal Bournemouth Hospital and reduced costs by 70% by composting 13 tonnes of used packaging. The airport could use compostable packaging so waste streams of recyclables have less contamination and non-recyclable waste rates would decrease.

4.4 Benefits of collaboration

This case study illustrates some of the benefits of collaborative work between an external commercial organization and a university. From an external organization's perspective, there are numerous reasons to enter into this type of activity; it provides:

- Access to internationally recognized academics with specialist knowledge and skills.
- Access to technical support and equipment that might otherwise be inaccessible, including resources such as professional/expert/research journals and specialist software.
- Access to motivated and enthusiastic under- and post-graduate students looking for experience.
- Access to new ideas, concepts, fresh approaches and modern thinking, as well as a more international outlook.
- An opportunity to undertake an activity that: i) is important but not a current priority or lacks resource; ii) will be a future priority but requires some advance work; iii) requires expertise or skills that are not available within the organisation's workforce.

In the specific case of the SIAL study, partners at SIAL were provided with examples of students' reports. SIAL took a highly positive view of the work, its message and recommendations made. Recognising the reported importance of food waste highlighted through the students' work (e.g. Plate1, Figures 1-4), a food waste system was subsequently implemented. The impacts of this system have not yet been determined or evaluated. SIAL also recognized the value of continuing work with the University of Southampton; ongoing work by a postgraduate MSc student is being undertaken, including an appraisal of the food waste management initiative.

From a university's perspective, there are also numerous benefits to enter into collaborative working with a local organisation:

- Access to practicing professionals with a deep understanding of the practical, logistical, financial and political implications of project/policy implementation.
- Improved employer engagement and student employability profiles and access to high quality work placements.
- Contemporary views of workplace timescales and financial constraints faced by commercial organisations.
- Large commercial organisations usually work to similar reliable and professional standards to universities in terms of health, safety and welfare rules and regulations, insurance cover

and Duty of Care requirements.

However, organizing and managing this type of collaborative activity through to a successful conclusion is not straightforward. Building a successful relationship between a commercial organisation and a university can take time and there may be barriers to overcome, including incompatible timescales, logistical and security issues, and health & safety considerations. These can be partially overcome by using a detailed, agreed joint process for the activity that is planned well in advance of the starting point.

4.5 Student performance

Despite extensive tutoring and mentoring, the students understandably made a number of mistakes, examples of which include:

- Assuming that the waste composition at the airport remained the same throughout the week and throughout the year
- Neglecting to recognise that they were given a sample of the daily waste collected and not the full day's waste.
- Failing to properly report the correct units of measure for some of the segregated data. Some results were reported in grams instead of kilograms and others reported larger amounts of segregated waste than was in the total bag to begin with. The obvious errors were adjusted; however, it is likely that some remained within the data set.
- Mis-sorting of the waste during the waste audit. The subjectivity of some categorizations could have led to differential sorting between each group. Communication between the students aimed to remove this bias; however, the first two groups used three categories for food waste and the final two used two.

Overall, the consultancy-style reports submitted by the students ranged from weak to excellent (mark range 30-75%; mean 56±13%) with 6 students obtaining distinction (mark >70%) grades and 8 students failing (mark <40%). We normally get marks higher than 75% in this type of assignment, sometimes even >90%, but in this case, the whole class made the first error listed above which limited our ability to award very high grades.

We have found that this type of bipolar mark range is common when we set real-world assignments for students. We feel this is because stronger students are able to utilise their creativity, making the most of their proactive and positive attitude and approach to study. Weaker students find it more difficult to problem-solve, manage their time effectively, work in teams and interact professionally with external organisations. Our analysis is that the stronger students are stretched but still thrive when required to collaborate with external organisations and find ways to demonstrate their high-level academic skills in a professional setting. The stronger students particularly enjoy and welcome the opportunity to show that they can be responsible for professional-standard tasks that lead to real changes to the operations of an external organisation. Weaker students find that their time-management, communication, presentation and team skills are put under severe pressure in this type of assignment and tend to struggle more than they would if they were simply asked to provide a standard essay as part of their assessment for a module. Nevertheless, these students learn a great deal from observing their peers and from seeing how much they need to improve if they are to operate in a professional environment; it simultaneously helps them to mature and acts as a wake-up call in terms of their employability skills. Both types of students utilise this experience to enhance their curriculm vitae. The amplified differences that emerge between the weaker and stronger students undertaking real-world assignments leads to the observed quasi bipolar range in marks, separating out students who are of high quality or ability from those that are less able.

An example of feedback to a student who performed well and scored a distinction for the coursework is shown in Box 1.

Unedited examples of verbatim feedback from the students to the staff are provided below; it is evident that the overall experience was generally positive but a number of grumbles are clear relating to timing of the work and submission date.

- “Relying on a class of 30 individuals (most of which don't know each other) to organise their own waste audit methodology was optimistic. It leads to people withholding key information which should have been shared evenly and people losing key data, limiting the accuracy of our analysis.”
- “The nature of the coursework (consultancy report) was much more interesting than an essay to research and write.”
- “I am pleased the cw assessment was a waste audit for a real client and required skills of reporting, data analysis and providing mock consultancy work - something which has been very useful in job applications and I can mention at interview stage.”
- “I felt the waste audit as a whole could've been better organised. The actual waste survey itself was relatively well organised on the day. There were issues with planning the audit before and a data collection system where I felt there was little guidance and students were left to themselves to do this. With a class of >45 students, there were too many students to get this nailed. This would've worked better in much smaller groups as I went into the survey not quite sure what was happening. There was a feeling of 'somebody will do it' but no leader or stepped forward or an assigned leader.”
- “Errors in data recording were quite disappointing. Leaving students to collate and share data with peers did not seem a very practical way of ensuring everything worked well.”
- “On the whole a waste audit is a good idea, especially with a 'big' client and I have learned a lot but I felt the organisation, information from the client and more understanding of existing WM practices at SIAL to make better, more informed recommendations in the report would've helped.”
- “The coursework was interesting and the opportunity to audit an actual business meant that I learnt a lot more than if it was a made up scenario.”

BOX 1 An example of feedback to a student who performed well in the assignment

Things that you have done well:

- You have fully "entered into the spirit" of the assignment. You have shown a willingness to "think outside the box", engage with new ideas and concepts, solve real-world problems with all their complexities and uncertainties, and have a go at unfamiliar tasks such as cost-benefit analysis. This is pleasing and bodes well for future academic work and professional employment tasks.
- You have addressed the set question rather than going off on a tangent of your own.
- You have stuck to the agreed word count. You have met the learning outcomes for the assignment.
- You have provided a suitable context for the study and a suitable structure for your report. The use of sub-headings helps the reader to navigate the document.
- You have addressed the key points we would expect to see covered in this assignment.
- You have demonstrated exceptionally comprehensive systematic knowledge of key aspects of the area of study and conceptual understanding of ideas and techniques relating to the application of the waste audit and circular economy thinking at SIAL.
- You have produced an excellent report that clearly identifies waste streams generated by the operations within SIAL; determined potential methods for reducing, recovering and/ or processing selected waste materials using adaptions to the current systems deployed; estimated the potential income/ reduced costs of each recovery method; identified and summarised new processes and/or industrial networks that incorporate circular economy thinking within the setting that could be practically and realistically deployed by SIAL. There are some minor errors here and there in the report and there is potential for improvement in some areas.
- You have provided a list of your top potential improvement projects, ranked by likely benefit. We could debate the accuracy of the income/ reduced costs and benefits of each of your selected improvement projects but in reality, you have made a good effort in terms of completing this activity.
- You have been able to pull all these different aspects together in a concise and authoritative fashion.
- You have provided evidence of appropriate and exceptionally wide reading of appropriate peer-reviewed and other authoritative materials relating to the assignment and its component parts. This has given you a huge amount of material to draw upon when putting together your discussion.
- There is clear evidence of critical evaluation of what you have read.
- The text you have written is highly competent in terms of communicating ideas problems and solutions, and highly competent in terms of contextualising knowledge and structuring/sustaining arguments.
- You have shown a high degree of technical and practical competence in using software i.e. use of Word and other software.
- The overall presentation of your work is very good. It is well-written, organised and in an appropriate format. The use of sub-headings, tables and figures really helps the reader to navigate the document. Your tables and figures are generally of a good quality and are clearly labelled and displayed. You have made superb use of supporting tables and figures of information, especially in the appendix.
- Citation and referencing is generally accurate, consistent and uses an appropriate style.
- You have provided an excellent statement of the conclusions from your report for the client.

Things that require improvement:

- There are a small number of minor errors in the text and on some figures. Spelling and typing mistakes and poor grammar/sentence construction should be avoided by using Word's spelling and grammar checker. Correct spelling and grammar is important.
- You have made some errors in estimating the annual waste arisings at SIAL – see comments on your submission.A small number of sentences could have been expressed better i.e. more concisely or in a clearer fashion. The listing of references contains a number of minor errors.

5. CONCLUSIONS

This paper describes and critically evaluates the approaches taken by groups of university students undertaking waste-focused activities that involve collaboration with an external organisation. It outlines the results of the waste audits, by quantity and composition, as well as discussing issues relating to contamination, communication, potential improvements and limitations of the approaches/methods selected. The benefits to SIAL, the students and the academics are discussed, together with the outcomes from this activity.

The audit has shown clear areas where Southampton Airport can improve on its waste management strategy to reduce the amount of waste it produces and to increase its recycling rate to above 35%. We recommend the airport focuses on reducing the mis-sorting in general waste bins to increase the materials being recycled. This should be done primarily by improving the labelling of the bins to show where common waste materials should be placed. If the waste can be diverted away from general waste and into the recycling bin, the airport will notice large economic savings. The airport should liaise with its contractor (Veolia) to collect food waste separately or alternatively the airport should investigate treating food waste on-site.

Targets for increasing recycling rates should be set and audits carried out periodically to check progress against these targets. Landfill and incineration cannot be seen as zero waste concepts and so in order to comply with the Waste Framework Directive (2008/98/EC), the airport should reduce the amount of general waste being incinerated through the use of the waste hierarchy in their waste management strategy. Waste and Resources Action Programme have created a free resource for businesses which creates a personalised waste action plan based on the waste hierarchy (WRAP, 2017). It is recommended that SIAL use this resource to further reduce their waste.

There is no doubt that this student-led learning activity stimulated interest, discussion and debate and generally raised students' and SIAL's employees' awareness of waste issues. In an educational context, there is considerable merit in prompting action learning of this ilk. Although students' levels of achievement and performance were highly varied, there is little doubt that this task stimulated independent learning and development of professional and employability skills. In particular, it provided a wake-up call to weaker students in terms of the personal skills and attributes they need to develop if they wish to work in a professional organisation. Due to the waste audit work being undertaken in groups, students also benefited from peer learning. From the perspective of SIAL, the students' activities and reports generated suggestions and recommendations that (1) may not have been obvious means to achieve better waste management, and (2) were based on quantitative evidence that may not otherwise have been made available. Certainly SIAL considered the reports and recommendations to be of sufficient quality to use them as the basis for management decisions.

As well as describing and evaluating the activity, this paper has showcased some of the learning materials developed, reported on the practical and logistical issues encountered, summarized results from the different activities, evaluated feedback from the students and the commercial organisation, and highlighted potential future developments.

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APPENDIX 1

Waste Audit (Student version): Southampton Airpor

Data sheet for recording sorted waste samples for the Waste Audit

Date of waste audit: ____________________ Auditors' Group: _______________________

Site: ________________________________ Source of sample: _____________________

Sample type: _________________________ Date sample collected: __________________

Sample/bag number: ___________________ Total sample weight: ___________________

Material	Weight of material/categories	Notes/Remarks
1. Paper		
a. *Office paper*		
b. *Magazines and printed materials*		
c. *Newspapers*		
d. *Foil*		
e. *Mixed paper*		
f. *Empty Waxed Paper Cup*		
2. Cardboard		
a. *Liquid cartons*		
b. *Other (including cereals boxes, etc)*		
3. Metals/Can Tins		
a. *Ferrous (e.g. steel, cast iron, wrought iron)*		

b. *Non-ferrous (e.g. aluminium soft drink cans, brass, copper, silver)*		
4. Glass		
a. Clear		
i. *Jars*		
ii. *Bottles*		
iii. *Other*		
b. Green		
iv. *Jars*		
v. *Bottles*		
vi. *Other*		
c. Brown		
vii. *Jars*		
viii. *Bottles*		
ix. *Other*		
5. Plastics		
a. Recyclable (High-Grade)		
b. *Non-recyclable (Low-Grade)*		
6. Putrescible/Organic		
a. Food Waste		
Avoidable		
Possibly Avoidable		

Unavoidable		
b. Garden Waste		
c. Other		
d. Contaminated packaging (MORE THAN ¼ FULL)		
Contaminated Plastic		
Contaminated Paper/Card		
Contaminated waxed paper cup		
Other contaminated Packaging		
7. Textiles and leather		
8. Rubber		
9. Construction Material		
Wood		
Scrap metals		
Ceramics and rubble		
10. Nappies and sanitary		
11. Other/mixed		
a. Batteries		
b. WEEE		
c. Other hazardous		
d. Other		