An Investigation Into Solid Waste Accounting In the New Student Union Building At the University of British Columbia

Lucy Bai, Joshua Chung, Jennifer Wong, Hoires Zhu

University of British Columbia

APSC 261

November 22, 2012

An Investigation Into Solid Waste Accounting In the New Student Union Building At the University of British Columbia

Prepared By: Lucy Bai, Joshua Chung,
Jennifer Wong, Hoires Zhu

Date of Submission: November 22nd, 2012

Course Name: APSC 261/2

Name Of Tutorial Instructor: Mr. Faizal Karim

Abstract

Waste accounting is a formal and structured process used to quantify the amount and type of wastes generated by a facility. In order to meet the waste reduction target and further the AMS Lighter Footprint Strategy, a waste accounting method is needed to measure the amount of solid waste generated in the New Student Union Building (SUB) on a weekly basis. By investigating the methodologies used by large institutions, a hybrid solution is then recommended.

This report will discuss the three major sources that are used as the foundation for the solution proposed. The recommended waste accounting method suggests formation of a waste sorting team to perform waste classification and also an implementation of covered automated weighing containers to measure the weight of sorted wastes and send the collected data to the Alma Mater Society (AMS) through a wireless network.

Furthermore, the report will focus in the triple bottom line assessment for the proposed solution to evaluate the feasibility of applying this waste accounting method in the New SUB. By analyzing its economical, environmental, and social factors, the method recommended is suitable for the New SUB as it has low maintenance cost, low ecological footprint, and minimal sociological impact on a long term basis.

Table of Contents

List of Tables and Figure

1.0 Introduction

The University of British Columbia (UBC) is in the process of constructing a New Student Union Building (SUB) beside the current SUB. The current Student Union Building has been in service since 1968, and as of September 2014, the New SUB will take its place. Being one of the busiest buildings on campus, students often dine, socialize, and attend special events in the SUB. Its high utility rate is directly related to the garbage generated inside the building. UBC has been actively taking part in the movement towards a more sustainable campus. As part of UBC's Zero Waste Plan, the Alma Mater Society (AMS) is setting a waste reduction plan for the new SUB. Before planning for reduction, it's important to find a way to accurately account for waste that is being generated in the building on a regular basis. The focus of the report is to evaluate waste accounting methods done by other large institutes, and based on the evaluations provide a plausible solution for the New SUB. The challenge with the traditional waste audit methodology is its reliance on waste audit companies. The audit carried out by private companies is a onetime solution and fails to provide a long term commitment to the waste accounting of the New SUB. Therefore our team proposes a custom waste audit system that is tailored to cater the New SUB.

2.0 Background Research

2.1 Past Waste Audits in UBC

UBC had done two waste audits in the past: one was conducted by the UBC Waste Management Division in 1998 and another one was directed by MJ Waste Solutions in 2009. The 1998 waste audit covers the entire UBC Vancouver campus while the more recent one only focuses on the waste generated from the SUB. These two waste audits deployed different methodologies in measuring the amount of wastes and separating them in distinct categories.

Spatial effects and temporal variation were addressed in the 1998 waste audit by dividing the campus into different activity areas and tracking the user flow over time. A minimum of three 24 hour samples of the waste generated in each activity area were collected. Following collection, sampled waste was separated into 13 major waste material classes and weighed. The category classifications used are listed in Table 1. The report written by the UBC Waste Management Division had noted that the time required for sorting the collected samples was 400 hours. By studying the pattern of per-user movement over space and time, the amount of waste generated was extrapolated. Furthermore, the predicted annual values were compared to documented landfill waste values to assess the validity of the waste audit method (Felder, Petrell, and Duff, 2001).

Table 1: Category classifications used in the 1998 UBC waste audit

Compostable material	**Recyclable**	**Residual**
Animal bedding Sawdust Woodchip bedding	Glass Beverage Container	Metal Ferrous
Animal waste Feces	Paper Newspaper Office fine paper Cardboard	Miscellaneous
Cloth	Plastic High density polyethylene Polypropylene Polyethylene terephthalate	Plastic Low density polyethylene polystyrene polyvinyl chloride
Food No liquids	Metal Aluminum	
Residual paper Contaminated Hygienic Moulded		
Wood		

The 2009 waste audit was prepared by MJ Waste Solutions and consisted of two phases to develop a waste management plan for the AMS operations located in the SUB. Phase 2, which took place in October 2009, had incorporated the system analysis of the solid waste and recycling system in the SUB when conducting the waste audit. The AMS staff arranged consultant access to the building and space. By working with the Sustainability Coordinator, MJ Waste Solutions established 17 categories for the waste sort. The categories are specified in Table 2. Pre and post consumer samples of solid waste and recyclables were collected from each floor of the SUB and were hand-sorted into the 17 material categories. Each material category was then weighed. The information was used to determine the overall waste composition of the SUB (MJ Waste Solutions, 2010).

Table 2: Waste sort categories used in the 2009 UBC waste audit

Old Corrugated Containers Shipping boxes Brown paper bags	**Food Containers** Metal food containers	**Textiles** Fabric material Bedding
Office Paper Printing/writing paper Books/magazines Newspaper	**Other Metals**	Wood Waste Dimensional lumber
Compostable Paper Tissue paper Paper towels	**Container Plastic** Food containers Cleaning products	**Liquids** Liquid detergents Oil
Refundable Beverage Containers	**Plastic Film** Clear film bags Shrink wrap	**Solids** Grease Solid heavy metals
Container Glass Food jars Medicine bottles	**Other Plastics** Polystyrene Styrofoam	**Miscellaneous Materials** Rock/dirt Rubber/tires
Non-container Glass Light bulbs Ceramics	**Food/Yard Waste**	

2.2 Waste Audits in McMaster University

McMaster University is located in Hamilton Ontario; the school stretches over 377 acres of land. In March of 2011, McMaster University hired the waste audit company, Waste Check, to carry out a waste audit in the functional areas on campus. The purpose for this research was to quantify and analyze the composition of waste streams generated by the campus. The data was then used to set up a Waste Reduction Work Plan for the university. The audit areas include Mils Library, The Student Centre (MUSC), the Residence Buildings, and The Commons. Various Kitchens and food tenants located inside these building also took part in the waste audit. Waste was collected over the course of 24hours at these 4 locations in which Waste Check reorganized into 3 waste zones: Residence Buildings, MUSC and Mils Library and The Commons. The waste collected was bagged and brought to an off-campus facility. The Waste Check audit team sorted 100% of the waste into different commodity and weighed each commodity bins. The data was logged by waste zones, and is summarized on table 3. Table 4 is the table of categories and sub-categories that is used to classify waste during the audit (Waste Check, 2011).

<u>Table 3: Final results of waste checks in McMaster University</u>

	Residence Building	Commons	MUSC and Mils Library
Annual Total Waste	385,147.89Kg	377,111.39Kg	645,264.12Kg
Paper	34.37%	9.96%	22.81%
Plastic	26.81%	35.24%	20.60%
Organic	28.74%	47.99%	49.21%
Glass	6.87%	2.50%	1.27%
Metal	2.04%	1.61%	1.00%
Other	1.17%	2.70%	5.11%

<u>Table 4: Final results of waste checks in McMaster University with categories and sub categories</u>

1. Paper Fibres	
Newspaper	ONP, Inserts
Magazines	OMG
Phone Books	OTB
Cardboard	OCC
Boxboard	OBB
Mixed Papers	Fine Paper, junk mail
Moulded Pulp	Egg Cartons, Trays
Books	Hard, soft cover
Kraft Paper	Paper bags
Spiral Wound	Frozen juice, Pringles
Tissue / Towelling	Tissue, napkins, paper towel
Gable Top Cartons	Milk, Juice
Aseptic Containers	Tetra Type Packaging
Other	Multi-layered, waxed

2. Plastics	
PETE Soft Drink	#1
PETE Other bottles	Water, Juice, Food, Trays
PETE Other Packages	Trays, Clam Shells
HDPE	#2
PVC Bottles	#3 & Packaging
LDPE / PP	#4 and #5 Squeezable
PS	#6, Trays, Cups (coffee), Packaging
Recyclable Film	Shopping Bags
Flexible Film	Garbage Bags, Chip Bags, Shrink
Wide Mouth Tubs	#2, 4, 5, 6
Other Containers	#7, unmarked plastics
Other Rigid Packaging	
Other Plastics	

3. Metals	
Aluminum Cans	Food & Beverage
Aluminum Foil	Trays, Foil
Steel Cans	Food & Beverage
Paint Cans	Empty
Other Metal	Scrap, other containers
4. Glass	
LCBO Clear	Clear Alcoholic Beverages
LCBO Colour	Coloured Alcoholic Beverages
Clear	Food & Beverage
Coloured	Food & Beverage
Other Glass	Light bulbs, Ceramics
5. Household Special Waste	
Batteries	All Types
Paint	Liquid residual
Oils	
Flammables	Solvents
Other	Sharps, Acids
6. Compostables	
Food Waste	All food waste
Flowers	
Yard Waste	Grass clippings
Animal Waste	Feces, animal litter & bedding
7. Other Waste Materials	
Textiles	Linen
Carpet	
Diapers	
Electronics/Computers	Small Appliances
Rubber	Tires, Mats, Tubing
Other	Materials not classified above

2.3 Residential Waste Study in Ontario

There were a lot of facilities that only acquired a large weighing scale to provide accounting of the weight of waste for their entire facility, but soon realized that the method is inefficient. Aside from the expensive weighing scale, the method still costs a hefty sum from various different aspects. An investigation of residential waste density study was conducted by a company in Ontario, as they suggested a better way of physically counting the waste. Rather than measuring the large volume of garbage directly, they would count the quantity of garbage bags, and multiply it by the assumed density. However, the density had to be standardized.

The management team investigated several different aspects of the waste generation, including density, forms, and other material properties. For classification, the waste was divided into two main categories: the "wet" organic wastes such as kitchen compostable, and the "dry" waste such as recyclables and fibers. The research was also done on different districts of the residential area so that the calculation would be more complete, since the data collected may vary in different public areas and their associated population density.

Table 5: Residential material density study results

Materials Density Study - Summary of Results

Material	Description	Number of Samples	Total Volume (m^3)	Total Net Weight (kg)	Density (lb/yd^3)	Density (kg/m^3)
Wet Bags (Cobourg curbside)****	bags of "wet" waste from the curb, noncompacted	3	3.41	640.0	316.6	187.8
Dry Bags (Cobourg curbside)****	bags of "dry" waste from the curb, noncompacted, recyclable paper fibre, plastics, metals, glass and textiles	4	3.56	244.0	115.5	68.5
Wet Waste (Guelph curbside)***	noncompacted bagged kitchen organics and other compostables such as diapers, tissue/toweling, animal feces and litter (packed, by hand, into weighing container)	2	1.25	524.50	705.2	418.3
Dry Waste (Guelph curbside)***	noncompacted, bagged recyclables fibre and container material (ONP, OBB, OCC, textiles, ferrous, PET, HDPE, LDPE, PP, glass etc.) and non-compostable residual waste (packed, by hand, into weighing container)	6	3.76	324.50	145.4	86.3
Organics (from Markham pilot area)**	bagged kitchen organics (packed, by hand, into weighing container)	4	3.18	1550.5	821.8	487.5
Garbage (from Markham pilot area)**	garbage in garbage bags and grocery bags (packed, by hand, into weighing container)	7	5.57	571.5	173.1	102.7
Fibre (from Markham pilot area)*	bagged fibre (ONP, OBB, OCC, fine paper, polycoat, magazines, glossy, junk mail) (packed, by hand, into weighing container)	5	3.14	891.0	478.9	284.1
Containers (from Markham pilot area)*	bagged ferrous cans, aluminium cans, PET , glass, HDPE bottles (packed, by hand, into weighing container)	5	3.14	181.0	97.3	57.7
Garbage (regular Markham garbage)**	garbage in garbage bags and grocery bags (packed, by hand, into weighing container)	5	3.98	328.0	139.1	82.5
ONP (from Miller MRF)*	stacked newspapers and magazines and other inserts (packed tightly by hand)	4	1.44	365.5	427.9	253.8
ONP (from Guelph MRF)***	newspaper, magazines, glossy paper, fine paper, junk mail, books (bobcat loaded)	3	3.37	412.50	206.3	122.3
ONP / Paper Mix (Northumberland MRF)****	newspapers and magazines, inserts, office paper, books (loaded by bobcat)	2	2.40	298.0	209.6	124.3
ONP / Paper Mix (Northumberland MRF)****	newspapers and magazines, inserts, office paper, books (packed flat by hand)	1	1.20	204.0	286.9	170.2
Fibre A (from Miller MRF)*	newspapers, magazines, glossy paper, fine paper, junk mail (Bobcat loaded)	5	3.14	1315.5	707.1	419.4
Fibre B (from Miller MRF)*	corrugated cardboard, boxboard, polycoat (Bobcat loaded)	3	1.88	170.5	152.7	90.6
OCC / OBB mix (Northumberland MRF)****	corrugated cardboard, boxboard, rolls, moulded pulp trays, kraft paper (Bobcat loaded)	2	2.40	110.0	77.4	45.9
OCC / OBB (Guelph MRF)***	corrugated cardboard and boxboard mix with some newspaper (bobcate loaded, approx. 3% newspaper)	3	3.37	145.50	72.8	43.2

Containers (Miller MRF)*	ferrous cans, aluminium cans, mixed PET, mixed glass, HDPE bottles (packed, by hand, into weighing container)	4	2.51	262.0	176.0	104.4
Ferrous Cans (Guelph MRF)***	ferrous food and beverage cans (gaylords directly off the sort line)	1	1.12	114.00	171.0	101.4
Ferrous Cans (Northumberland MRF)****	food and beverage cans (no compaction at MRF)	1	0.80	78.0	163.7	97.1
Alum. Cans & Foil (Guelph MRF)***	aluminum food and beverage containers and aluminium foil and trays (packed, by hand, into weighing container)	2	2.25	101.00	75.8	44.9
Aluminium Cans (Northumberland MRF)****	aluminium beverage cans (hand loaded with no compaction at MRF)	2	1.77	74.0	70.6	41.9
Aluminium Foil and Trays (Northumberland MRF)****	aluminium foil and trays (hand loaded with no compaction at MRF)	2	1.95	58.0	50.1	29.7
PET (Guelph MRF)***	non perforated food, beverage and other PET containers (all sizes - packed, by hand, into weighing container)	5	5.62	184.50	55.4	32.8
PET - perforated (Guelph MRF)***	perforated food, beverage and other PET containers (all sizes - packed, by hand, into weighing container)	3	1.93	109.50	95.8	56.8
PET (from Northumberland MRF)****	non perforated, all sizes with no compaction at MRF	1	2.23	68.0	51.5	30.5
HDPE Bottles (Guelph MRF)***	HDPE food & beverage bottles and other HDPE bottles (packed, by hand, into weighing container)	4	4.50	125.50	47.1	27.9
HDPE (Northumberland MRF)****	mixed HDPE bottles and jugs (hand loaded into gaylord)	2	1.96	74.0	63.5	37.7
PS (Northumberland MRF)****	mixed white trays, cups, insulation board	2	2.35	22.0	15.8	9.4
Wide Mouth Tubs/Lids (Guelph MRF)***	food and beverage tubs and lids, other tubs and lids, HDPE, PP, LDPE (packed, by hand, into weighing container)	1	1.12	36.50	54.8	32.5
Wide Mouth Tubs and Lids (Northumberland MRF)****	#2, #4 and #5 wide mouth tubs and lids with some #5 bottles	2	1.95	61.0	52.8	31.3
Film Plastic (Guelph MRF)***	compressed recyclable LDPE bags and wraps, grocery bags, garbage bags, etc. (packed tight by hand)	3	1.88	124.00	111.1	65.9
Recyclable Film (Northumberland MRF)****	clean plastic bags, all sorts (not compressed much - hand loaded)	2	2.40	40.0	28.1	16.7
Textiles (Northumberland MRF)****	clothes	2	1.93	206.0	179.5	106.5

In order to develop a method similar to the one introduced by the study, a large amount of prepositive investigations and analysis of data collections had to be done. However, the system would maintain itself in the long run with desired economical benefits, along with minimal impact on the environment. Due to the change in available mix of recyclables and individual material densities, additional field density studies will need to be done to keep an accurate bias for future calculations.

3.0 Recommended Method

The recommended approach is of a hybrid nature from all the solutions discussed and researched thus far. To obtain the most detailed data distribution of the solid waste generated in the new SUB, whilst keeping in mind of the available resources, it is best to look at the recommended approach in the most prominent three aspects: economical, social, and environment. The recommended method of waste accounting is of follows:

- Two part implementation: Collection System implementation, and Waste Sorting System implementation
  - Collection System: Covered Automated Weighing Containers, and Disposal System (To be implemented in the future, as an expansion project)
  - Waste Sorting System: Human Resources Assembling, and Training Program
- Maintenance: Collection System Maintenance, Training Program updates

The collection system includes two parts: the covered automated weighing containers, and disposal system. The covered automated weighing containers are a product not readily available on the market but are relatively easy to produce. An alternative to contracting an external supplier to prototype this design is to involve the students of UBC to assist in the making of these containers. These containers are ideal projects for students of the Engineering background, especially for Electrical, Computer, Mechanical, and Materials Engineering undergraduate students. This container design involves a large lid-covered bin, with a scale at the bottom of the bin, and a wireless connection to the internet. The goal of this design is such that these bins will take automated measurements and send them to the AMS Waste Audit Team for further analysis at the end of the collection period.

The large lid-covered bins average around $100 to $200 in Canada depending on the size, material, and supplier. An industrial weighing scale averages around $400, and a wireless connection device attachment costs around $150. It is imperative to keep in mind that student involvement and faculty support is crucial in keeping the starting capital within manageable levels. Each bin is estimated to cost around $800. The number of bins required would depend on how detailed the sorting process is. The estimated number of bins needed for startup would be six, one bin for every type of material processed, based on McMaster University's waste audit report. However the six types of waste the sorting process will generate can be decided by the AMS Waste Management Team as they see fit. The AMS could request for additional bins to improve the range of data as they deem reasonable.

The disposal system is an add-on program after the installment of the initial audit scheme. The individual bins containing sorted waste are removed under the label of "waste" after the audit process. An additional disposal system to dispose the waste inside each bin based on the material each bin houses is a potential first step in reducing total non-recyclable waste output. This suggestion is completely under the discretion of the AMS, and is beyond the scope of this waste audit solution.

The waste sorting system includes two parts: the human resources hiring, and its training program. Based on previous UBC waste audits, 400 hours were required on average to sort the waste into 13 different categories by a six member sorting team. After calculation of the amount of work needed per member per day, and the consideration of the prospect of waste output of the New Student Union Building, the suggestion came to be that the human resources required for this job includes six full time janitor and one full time data analyst or accountant. It is to note that these positions will be full time and the waste audit period will be on a bi-weekly basis (per one sample of a 24 hour period). The average time a member of the sorting team will be expected to work is approximately seven hours a day. The average wage of the janitors can follow the standard average custodian wage in Canada, which is $15 an hour.

The initial training program will include how to distinguish the types of plastic, metal, and food waste that are recyclable, decomposable, or neither. It is important for the sorting team members to be able to accurate identify different types of plastic and metal and their associated recyclability to ensure that the sorting process produces the best results. There is an emphasis on the initial training of the sorting team members due to the fact that the more proficient the sorting process is, the more accurate the waste audit results will be.

Figure 1: Flow chart of recommended method

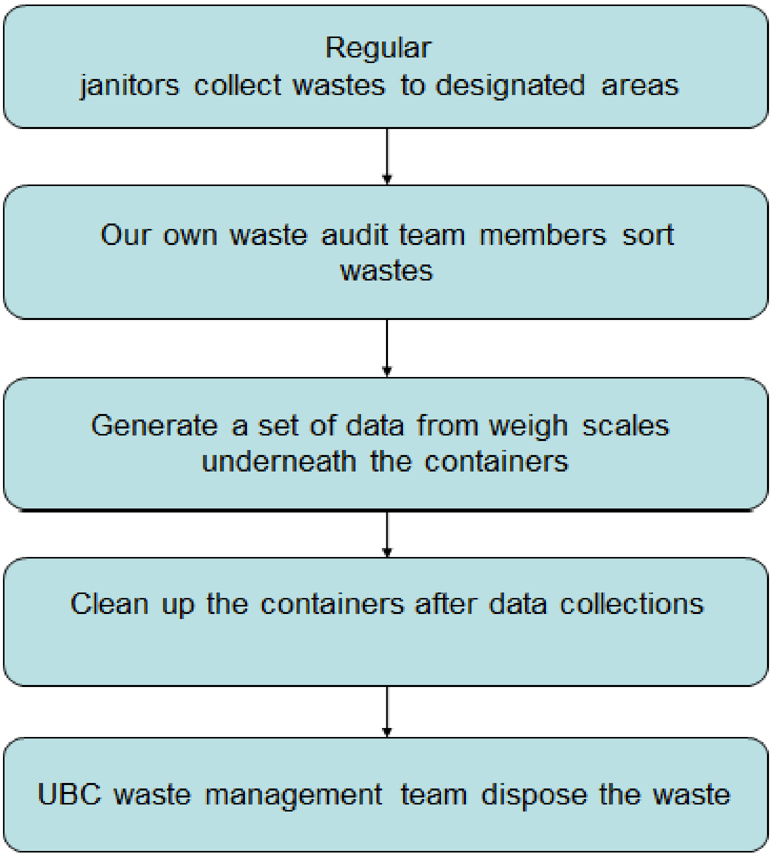

Figure 1 provides an overview of the waste audit method that this report recommend. This method will work with UBC Waste Management without causing any major changes to the existing routine. The janitors of the new SUB building will gather the garbage into their usual collection bins and the sorting team will take over after the day's worth of waste has been collected to start the sorting process. The sorting process will take approximately one week and at the end of the process, the individual bins will get measured in terms of their weights and the AMS will obtain the associated data through the automated weighing bins. This routine completes one waste audit period.

The waste audit can be done within the given collection space made available within the current SUB. The regular waste collection space can also double as the space of operation for the waste audit team. It is to note that the required facility for the waste audit sorting should be a well-covered and sheltered space; therefore, it is suggested that the SUB enhances its waste collection space to include an additional roof. The individual bins and sorting process are designed to minimize the amount of space needed; as a result, allows the waste audit to be done on campus, right at the SUB.

The foreseeable maintenance required would be on the covered automated weighing containers and the training program updates for the sorting team staff. The covered automated weighing containers will only require check up on a half year basis, similar to most electronic alarm systems, and can be done safely and efficiently. The updates on the training program for the staffs are needed due to any changes of government regulation and definition changes of certain materials and their recyclability.

4.0 Triple Bottom Line Assessment

4.1 Environmental

One of the greatest benefits of the proposed system for the new SUB is its minimal environmental impact. Its location is close to the garbage source, and makes use of an existing facility by minor modifications. The existing garbage docking platform in the current SUB will be utilized to house the proposed waste audit system. As a result, only a roof will need to be added as the construction of the new facility. Minimal construction is crucial for minimal ecological disturbance for the environment. The proposed waste audit system's location is just metres away from the New SUB; this means the waste transportation to the audit facility will not require carbon emission through the use of vehicle transportation. Successfully reducing carbon emission and other negative environmental impact associated with transportation. If the New SUB outsource to a private company, the waste samples would need to be transported by trucks to off campus facilities for every audit.

Garbage trucks in Vancouver typically run on a diesel engine and they are classified as Class 7 heavy duty vehicle. Class 7 HDDV produces 0.2, 0.1, 15.5, and 0.14 grams per mile of NOX, PM, CO and NMHC. Older vehicles of this class could produce 20 times as much NOX and 10 times the PM. (Levelton Consultants Ltd, 2005)

For example: Urban impact is the closest waste audit company to UBC campus; they are located at 15360 Knox Way, Richmond. According to Google map, it is 24.3km from UBC SUB, or 15miles. A round trip of the waste collection by this company will be 30miles per trip; if we assume the waste audit happens twice a month that equals 24 trips per year. Table 6 shows that an additional 11,476.8g of air pollutant can be saved if we choose to stay local and have the waste audit facility in the SUB.

Table 6: Air pollution emission by a typical garbage truck

	NOX 0.2 g/miles	PM 0.1 g/miles	CO 15.5g/miles	NMHC 0.14 g/miles	Total Air Pollutant
Grams per trip	6g	3g	465g	4.2g	478.2g
Annual total	144g	72g	11,160g	100.8g	11,476.8g

*This calculation is for a single Class 7 Heavy duty garbage truck.

4.2 Economical

Monetary factors are involved in each and every single process within the proposed method for waste auditing in the New Student Union Building. In order to thoroughly analyze the expense in terms of monetary values, it needs be broken down into several different categories for corresponding researches and comparisons. In this case, the expense will consist of labor, construction and equipment costs.

According to the proposed method, there will be six full time sorting team members hired, in addition with one full time data analyst or accountant. In comparison to the fifteen-dollar average wage for janitors working in British Columbia, the wages of sorting team members should be slightly higher due to the fact that the hourly workload is denser than normal school janitors, which will be around 16 dollars. Based on data extrapolated from past waste audits done in UBC, it takes approximately 35 hours of work for six workers to sort the waste into 13 different categories in the current SUB. Correspondingly, roughly the same amount of time will be taken in the New SUB.

The majority of starting capital goes to the infrastructure of the waste auditing process. Depending on the policies that UBC implements, the expense may vary on a large scale. For the worst case, all the equipments will be purchased from external sources. A set of equipments consists of an industrial bench scale with acceptable accuracy which will value around 400 dollars on average, a wireless connection device attachment with estimated cost of 150 dollars and a 150 dollar lid-covered bin.

The proposed method only requires ignorable financial constructional supports, therefore the starting capital can be simply approximated as the total expense on sets of equipments with the training fees for newly hired sorting team members depending on the AMS' demand, in which for the worst case, is around 4000 dollars. The long term expense would be just the wages for sorting team members and the maintenance fees for the equipments. By comparing this method to outsourcing the waste auditing to other companies, the cost is definitely going to be more than just worker wages. In addition, we could utilize internal sources within the UBC community so that the starting capital could be significantly reduced through modified designs and faculty forces.

4.3 Social

In order to access the recommended method by its social aspects, the following criteria have been evaluated: safety, hygiene, and school involvement. Moreover, its effects to the janitors from the waste sorting team, UBC Waste Management, and the general public will also be discussed.

The recommendation suggests that regular maintenance for the covered automated weighing containers and training program updates for the sorting team staff are required. A minimal of half-year check up for the containers ensures the weighing scale and wireless connection are functioned properly. Also, updates on the software for the data collection system are maintained. Furthermore, the training program equips the waste sorting staff with knowledge on waste classification and material recyclability, and also assists the staff to be familiar with government regulations, especially health and safety regulations. Therefore, regular maintenance and training program updates provide a safe and efficient waste sorting and data collection.

The recommended method also encourages school involvement as the project is a good opportunity for UBC Engineering undergraduate students to apply their knowledge by designing and implementing the automated weighing containers. For example, students from Electrical Engineering can work on the electronic scale and the program for storing and analyzing the collected data while students from Mechanical Engineering can design the containers with considerations such as size, material, and durability. Therefore, student participation can enhance their learning experience and contribute their efforts to the sustainability development in UBC.

With the implementation of the covered automated weighing containers, the AMS Waste Management Team is able to collect the data efficiently, and thus minimizing the janitors' labor work. Also, the waste sorting area is sheltered and ventilated to ensure a safe and hygienic working environment for the waste sorting staff. Moreover, hiring a waste sorting team to handle the waste auditing minimizes disruption to the regular waste collection system, which is handled by the UBC Waste Management.

Even though waste audit aims to gather information to work toward a waste reduction plan, having a waste management team to do the waste sorting may discourage users in the New SUB to dispose the waste properly since they will know there is a team of people doing the sorting for them. Therefore, it is important to raise the public awareness to distinguish between solid waste and organic waste (compost).

5.0 Conclusion

The recommended waste audit method fares well in all aspects in terms of economical, social, and environmental standards. In terms of economics, although the proposed solution has a large starting capital, the long term maintenance cost and efforts are minimal in comparison to other waste auditing methods. By considering the length of this project, it is crucial to keep in mind the maintainability and financial feasibility of the project. The lengthy nature of this project is also why long term financial benefits are our priority in our economical analysis. In terms of social impact, the suggested solution brings forth more benefits than harm. Even though this method might discourage students to sort their own waste, the student involvement that this method proposes will definitely be more of an impact to the UBC community as a whole. The educational benefits and learning experiences that accompany this solution align perfectly with both educational goals of UBC and UBC's aim to focus on student involvement on campus. In terms of environmental concerns, the recommended method offers little to no carbon emission post-implementation. Although there are significant start up carbon emission concerns, the long term emission is near zero. Due to the localization of all the waste processing and sorting, minimal carbon emission is produced through the need to transport the waste.

Overall, the recommended method of waste auditing is sound, feasible, and optimal in regards to the aspects of economical, social, and environmental standards. As a result, this method is proposed to be the solution to the problem of solid waste accounting that this team has put forth.

References

Ashwood, K., Grosskopf, M., & Schneider, E. (1996, September). Conducting a Waste Audit and Designing a Waste Reduction Work Plan. Pulp & Paper Canada, 97(9), 84-86. Retrieved October 15, 2012, from: http://ezproxy.library.ubc.ca/login?url=http://search.proquest.com.ezproxy.library.ubc.ca/docview/232782577?accountid=14656

Chopra, S. (2004). Quantification And Composition Audit of Waste Generated At the Early Morning Market in Vientiane, LAO PDR (Master's thesis). Retrieved October 10, 2012, from: http://www.utoronto.ca/waste-econ/Sangeeta%20Chopra.pdf

Envirosris. (2001) Residential Waste Materials Density Study. Retrieved from: http://www.wdo.ca/files/domain4116/Access%20OPT_ORG%20R2-02.pdf

Felder, M.A., Petrell, R.J. & Duff, S.J.B. (2001). A solid waste audit and directions for waste reduction at the University of British Columbia Canada. *Waste Manag Res*, 19(4), 354-365. doi: 10.1177/0734242X0101900412

Levelton Consultants Ltd. (2005). *Heavy-Duty Diesel Vehicle Emissions in Greater Vancouver.* Richmond, B.C. Retrieved from: http://www.epa.gov/ttnchie1/conference/ei14/session8/ergudenler.pdf

Living In Canada (2012) Average Canadian Janitor’s and Caretaker’s Salary, Retrieved from: http://www.livingin-canada.com/salaries-for-janitors-and-caretakers-canada.html

MJ Waste Solutions. (2010). *Student Union Building: Phase 2 Waste Audit Findings and Updated Waste Management Plan (final report)*. Sarnia, ON: O’Donnell

Waste Audit. (2011). In *Urban Impact*. Retrieved October 31, 2012, from http://urbanimpact.com/waste-audits/

Waste Check. (2011). Waste Audit Report for McMaster University. Hamilton, Ontario. Retrieved from: http://www.mcmaster.ca/sustainability/documents/Waste%20Audit%202011.pdf