UBC Social Ecological Economic Development Studies (SEEDS) Student Report

An Investigation into the implementation of a solid waste accounting system in the new Student Union Building

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APSC 261

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An Investigation into the implementation of a solid waste accounting system in the new Student Union Building

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ABSTRACT

In this paper, we outline our process and investigation into the implementation of a solid waste accounting system in the new Student Union Building (SUB). Our investigation begins at the source, the disposal of trash items from the individual using or passing through the SUB facilities. From here the trash processes is followed through the collection and storage in the trash room in the SUB, and finally pickup and delivery to UBC's organic trash digester in the case of the organic waste, and pickup with destination to the Delta Landfill in the case of the inorganic waste.

It was determined that the implementation of a solid waste accounting system to quantify the amounts of each type of waste being produced is very feasible and can in fact be used as a tool to also implement several social and economic improvements to the SUB. The ideal step in the process to implement such an accounting system was at the point of storage before pickup.

It is our recommendation that the new SUB use the current Schaefer bins to continue to collect trash items, however build socially appealing wooden cabinets around them labelled with the final destination of the trash items, ultimately creating a sense of local awareness in the individual disposing of his or her trash items by informing him or her as to the closeness to home of the final resting place of that piece of trash.

These cabinets would be designed such that they could have a door which would swing open allowing the Schaefer bins to be wheeled to the trash room in the SUB. Here mechanical Schaefer-lifters could be used to empty the organic waste bins into a dumpster and the inorganic waste bins into a compactor. Using these mechanical lifters recognizes a social benefit in the employee not having to physically lift the Schaefer bins to empty them, mitigating the risk of back injuries or other lifting-associated injuries.

Finally, each the dumpster and the compactor would be sitting on four weigh scales, one beneath each corner, which would remotely relay the weight of the dumpster or compactor to a local software unit installed on a computer in a nearby office. Knowing the weight of the empty

dumpster or compactor, the program is thus able to track, plot and monitor the weight of each vessel, recording the history for later review. Based on this information, optimal pickup schedules could be determined such that fossil fuels burned by pickup vehicles are minimized.

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GLOSSARY

Compost – See organic waste.

Custodial staff – Employees of the University of British Columbia hired to clean and maintain campus facilities, which includes the emptying of solid waste containers throughout the Student Union Building.

Environmental footprint – A relative scale used to compare the severity of adverse impacts on the environment.

Ergonomics – The study of physical human interaction with their working environment with the aim of providing working conditions with maximum comfort and productivity while minimizing stress and working strains which could potentially lead to long term strain injuries.

Hazardous materials – Materials such as broken glass and other sharp objects, corrosive materials, bio-hazardous materials, or any other type of material which could cause harm if unexpectedly put in contact with human limbs.

Inorganic waste – Disposable trash items composed of materials other than plant or animal materials such as glass, plastics and foils.

Landfill – The final disposal site for inorganic waste items once they have been collected. The primary landfill in the Vancouver area is the Delta Landfill, located in Delta.

Lifecycle – The lifecycle of solid waste items in the Student Union Building begins with the disposal of the item by the individual in a waste receptacle, the collections and transportation of the waste amassed in these receptacles to the storage room in the Student Union Building, and the pickup and delivery of the trash items to their final resting destinations, be it the Delta Landfill for inorganic waste, or the University of British Columbia digester in the case of organic waste.

Load cells – Weight measuring mechanisms which typically operate by measuring the strain associated with an applied force and calculating the mass associated with this force. There are usually several load cells within a single weigh scale for increased accuracy and redundancies.

Organic waste – Disposable trash items often composed of plant or animals materials and usually require relatively little time to decompose.

Social awareness – A conscious sense of knowledge or importance of sustainable issues and their connection to society.

Triple bottom line assessment – A study or score of a project which considers and quantifies both environmental and social considerations in addition to financial considerations.

LIST OF ABBREVIATIONS

CIRS - Centre for Interactive Research on Sustainability

SUB – Student Union Building

UBC – University of British Columbia

1.0 INTRODUCTION

Being a North American leader in sustainable technologies and practices, the University of British Columbia is continually striving to decrease its environmental footprint through many reduction programs. This report addresses one of those programs, the initiative to attain a waste-free UBC. By performing an investigation into the implementation of a solid waste accounting program, recommendations are made throughout this report to ultimately achieve a tool that can be used to monitor the progress of the waste-free UBC initiative within the new Student Union Building. The objectives and scope of the investigation are outlined below.

1.1 PROJECT OBJECTIVES

The primary objectives for this project are as follows:

- Determine the most effective method to sort organic and inorganic wastes;
- Develop a method to quantify both organic and inorganic wastes;
- Determine and recommend a collection frequency for waste pick up from the SUB that minimizes life cycle fossil fuel usage;
- Develop ergonomically friendly operations to be carried out by custodial staff.

1.2 SCOPE

The scope of this project is as follows:

- Develop a solid waste accounting method for the SUB only, not the entire campus;
- Only consider landfill and compost (organic and inorganic wastes) and not recycling products.

2.0 WASTE SORTING – ORGANIC VERSUS INORGANIC

2.1 CONSIDERED CONCEPTS

Given that there will be a future ban on organic waste material in landfills in the province of British Columbia, it is imperative that organic wastes are separated from inorganic wastes on site. This can be achieved by one of several different methods: hiring manual labour to physically sort through solid waste collected from the SUB, or by creating the infrastructure for the general public to sort these materials as they are disposed.

2.2 CONSIDERATIONS FOR EACH CONCEPT

Hiring manual labour would require a lower initial cost however would involve continuous payments for continuous labour. From a social aspect, sorting through garbage is not a particularly clean or healthy occupation, and there is the risk of injury by glass or other hazardous materials.

Developing the infrastructure to allow for people to dispose of their organic and inorganic waste products includes a higher initial cost to purchase additional trash receptacles however this is essentially a one-time cost aside from minor maintenance costs to the trash receptacles. However, savings can be recognized by reusing the existing Schaefer bins currently located in the SUB. Through the reuse of these existing facilities, the initial purchase cost is lowered slightly, only requiring the purchase of a limited amount of Schaefer bins for the new SUB.

2.3 RECOMMENDATION

After reviewing the options, it is our recommendation that the SUB place an emphasis on sorting organic wastes from inorganic wastes by implementing different trash receptacles for organic and inorganic wastes respectively. There is evidence that shows that by providing this option to occupants of the building, people are more conscious about the decision they make in disposing of their trash. The CIRS building is a proven example of this phenomenon; both compost and inorganic waste receptacles have been installed and there has been a significant behavioural shift towards the use of compost receptacles. Another reason that this solution is preferred is because it represents a proactive solution where the different types of wastes never intermingle, and hence there is no need for sorting. However, hiring manual labour to perform the sorting is somewhat of a reactive solution which attempts to solve the problem after the fact.

There are also two major social benefits to this solution: first, a potentially hazardous operation is avoided altogether where custodial staff are not required to manually sort through the solid waste thereby mitigating the risk of hand injuries caused by hazardous materials such as broken glass.

The second benefit to this solution is that it provides an opportunity to influence social awareness in the individual depositing his or her trash items regarding the local impacts of his or her disposal actions. This can be done by building visually appealing wooden cabinets around the Schaefer bins that can be labelled not with the type of trash it is to house, but with the final destination of its location. The University of Idaho has implemented similarly labelled wooden cabinets, as seen in Figure 1, but we recommend taking this one step further through the use of the labels “UBC Compost Digester” in the case of the organic waste, and “Delta Landfill” in the case of the inorganic waste.

Figure 1 - Labeled Wooden Cabinets (University of Idaho).

Image sourced from http://www.uidaho.edu/dining/sustainability

3.0 TRANSPORTATION AND COLLECTION UNITS

3.1 CONSIDERED CONCEPTS

In many facilities and institutions throughout the world the current methods for transporting organic and inorganic wastes range from conveyors to rolling trash bins. In this report we have considered Schaefer carts, non-rolling bins, waste conveyors, and building waste chutes. Each concept included both positive and negative aspects in terms of environmental, social and financial considerations.

3.2 CONSIDERATIONS FOR EACH ALTERNATIVE

Schaefer Carts

The use of Schaefer Carts, as in Figure 2 below, provides an ergonomic, economic and familiar solution. The receptacles have wheels so that custodians are not required to lift heavy loads risking potential injuries such as back strains. Additionally the units are quite economical ranging from $100 to $200 per unit depending on volume and quantity of units purchased at a time. Each Schaefer cart has a life expectancy of around 10-15 years and a 10 year warranty as per SSI Schaefer. Moreover, many manufacturers such as Schaefer US use partial or fully recycled materials in their carts. By using fully or partially recycled containers the units further reduce the SUB's environmental footprint on a larger, more holistic scale.

Figure 2 – Various sizes of Schaefer carts (MidAtlantic Waste).

Image sourced from http://www.midatlanticwaste.com/container.html

Non-Rolling Units

Non-rolling units such as in Figure 3 provide a lower initial cost ranging from $15 to $47 per unit as per the supplier Belson Outdoors and can still be made from recycled materials providing similar environmental advantageous as the Schaefer carts. However, the main disadvantage to this concept is the additional strain and risk of injury placed on custodial staff during the lifting of these units to transport and empty them.

Figure 3 - Non-Rolling Waste Container (Landmark Series®).

Image sourced from http://www.belson.com/lsgsc.htm

Waste Conveyors

Waste conveyors have been installed in numerous industrial environments as well as similar institutions worldwide (Mayfran International, 2012). However, the impacts on the current design of the new SUB would include large modifications resulting in high construction delays and incurred cost. In some areas the building would have to be completely redesigned to allow room for the conveyor system. Additionally, the life cycle costs including purchase, maintenance and repairs of the conveyer system would be extremely high. The installation of a single central conveyer system for both the inorganic and organic wastes would require separation after they arrived in the building waste room, creating an additional step after the wastes have already been sorted. However, the installation of two conveyer systems would require even more modification to the already approved design for the new SUB causing monumental construction delays and unjustifiably high costs as a result.

Waste Chutes

Waste chutes have been a keystone component in many waste reduction strategies and documented fairly well especially in Australia (North Sidney Council, 2012). They allow for easy top-down transportation between multiple levels of the building, condense all waste into a main area, and provide an easy transportation method to reduce strain on workers. However, despite these positive aspects waste chutes share a similar downfall to conveyer systems: there would be an additional sorting step or alternatively the installation of two waste chutes. Additionally, the current design of the SUB would have to be adjusted to accommodate for one or more chutes creating an additional financial cost and construction delays. Although the chutes are convenient, there would also be an additional maintenance cost associated with chute cleaning and odor reduction. These chutes also create nesting places for insect pests such fruit flies which create additional unnecessary health concerns.

3.3 RECOMMENDATION

The final recommendation for the transportation method would be 240 liter Schaefer carts for inorganic wastes and 140 liter Schaefer carts for organic wastes as shown in Figure 4 and Figure 5, respectively. The reason for the difference in sizes is to address the fly and odor issues outlined in the 2010 SUB Waste Audit. At the time they were using 240L Schaefer carts for their paper products, bottles and cans, and organic and inorganic wastes. While this worked quite well for the bottles and cans, paper product systems, and inorganic wastes, the organic wastes presented issues with fruit flies and black flies due to infrequent disposal (Waste Audit Results and Waste Management Plan, 2010). Therefore, by reducing the size of organic waste bins it will force more frequent disposal, keeping the internal portions of the SUB cleanlier and less odorous.

In generally, the benefits of the Schaefer carts largely outweigh those of the alternatives. The simplistic design typically manufactured with injected molded plastic, but with the option of recycled plastic construction results in low environmental impact during production. In addition, by continuing to use Schaefer carts as in the old SUB, and simply changing the size of the carts used for organic waste, many of the current Schaefer carts could be reused in the new SUB, thereby further reducing environmental impact.

Moreover, Schaefer carts allow for sorting before the accounting process and maintain separation between inorganic and organic wastes throughout the lifecycle of the solid waste disposed in the SUB. An important consideration that must be recognized is that because the new SUB is already under construction the requirement for non-design altering solutions are highly. Rolling Schaefer carts provided this solution with low economic and social impacts. There are no structural design changes required, no new training needed for employees, and the majority of the 240 liter Schaefer carts can be carried over reducing the capital cost of the new waste management system.

Finally, with the current SUB there is one major downside to using Schaefer carts. After disposal of inorganic or organic wastes there is a routine cleaning process that must obeyed. By maintaining some of the labour within the waste management process there is a slight economic impact because of increased labour time. However, this process isn't entirely negative. This slight economic detriment during the disposal process is justified by a positive social consideration recognized by maintaining the custodial workforce and not replacing current jobs with automated systems. This balance between social, economic and environmental considerations points to Schaefer carts as the ideal transportation and collection unit to be used in the new SUB.

Figure 4 - 240L Schaefer Carts Reusable in NEW SUB (Waste Audit Results and Waste Management Plan, 2010).

Figure 5 - 140L Schaefer Carts (North Vancouver District, 2012).

Image sourced from http://www.dnv.org/article.asp?a=2093

4.0 ORGANIC QUANTIFICATION AND STORAGE

4.1 CONSIDERED CONCEPTS

We considered several methods of quantifying the amounts of organic waste, some of which take measurements at the start of the organic waste lifecycle, some of which take measurements in the middle, and some towards the end.

Considering the beginning of the lifecycle, custodial staff suggested we install local sensors on each container and connect them to a larger data collection center. These “smart” rolling units could track the current waste production immediately after stakeholder disposal. During consideration of mid-lifecycle measurements we proposed a solution that the Schaefer carts were picked up using a hydraulic arm system that contained load sensors. The arms would record the difference in weight of the Schaefer carts as they were lifted and lowered, and that measurement would represent the organic waste added to the dumpsters as depicted in Figure 6 below. An alternative mid-lifecycle tracking method is by simply placing weigh scales containing internal load cells under all of the new SUB’s organic waste dumpsters.

An end lifecycle accounting method was inspired by weigh scale technology in the petroleum product industry. When loading asphalt into tanker trucks, they first arrive on site empty and are weighed in on a large industrial weigh scale. Once having picked up a complete load, these trucks are then weighed again on their departure from site. The difference in the two weight measurements recorded would then have to be the weight of the asphalt that was loaded into the truck. By installing such a weigh scale on site here at UBC near the new SUB, organic waste pickup vehicles could weigh in similarly to the asphalt trucks, then once having emptied the organic waste dumpster into the truck, could then weigh in again upon leaving for UBC’s organic waste digester. The difference in the two recorded weights would then be the weight of the organic waste collected.

Figure 6 - Hydraulic Lifting Scale System (Nationwide Industrial Supply).

Image sourced from http://www.nationwideindustrialsupply.com/departments/warehouse-equipment/fork--dumper/

4.2 CONSIDERATIONS FOR EACH CONCEPT

Smart Rolling Units

Installing individual scales in each rolling waste container, or Schaefer cart, would provide a rapid accounting method. Each unit would tie directly into a larger database or network and quantify the amount of waste produced in the SUB. Additionally, because of the individual sensors in each Schaefer cart, UBC could obtain data on which locations throughout the SUB produce the most organic waste and potentially use this data in future considerations. The major downside of this system is the maintenance and initial cost of the network. Each Schaefer cart would be individually equipped with wireless scale as in Figure 7 below and a transmitter costing over $100 apiece as sourced from Fystore.com. These scales would have to be individually serviced and calibrated annually to maintain manufacturer load cell calibration standards. Moreover, because there would be approximately 30-60 Schaefer carts (based on approximately double the current SUB) throughout the new SUB. Service staff would have to keep records of which units had been serviced as well as constantly inspect the operation of all units. The total capital cost for this system would be approximately $3000-6000 plus the costs of installation and training in verification and calibration of the units.

Figure 7 - Wireless Load Cell for Individual Collection Units (Loadstar Sensors).

Image sourced from http://www.loadstarsensors.com/pr-di1000z.html

Hydraulic Arms

A mid-lifecycle accounting method would be using a torque sensor combined with specialized Schaefer cart lifting arms. The system would record the difference in weight between lifting and lowering the Schaefer carts, where the difference in weight recorded would be the weight of the organic waste collected. One of the major benefits behind this system is that it eliminates the risk of back injury, or falling objects as the containers are gripped and lifted entirely mechanically. The total approximate cost for this system is an estimated $4500 which includes the hydraulic dumping system, the torque load cell and the data acquisition system which are available from the companies Ergodynamics and National Instruments.

Weighed Disposal Container

The second mid-lifecycle accounting process incorporates a typical dumpster and the use of load cells to record the active weight. The dumpster seen in Figure 8 is a typical UBC waste container. The container would be placed with each of its four wheels on low profile industrial weigh scales comprising of an internal load cell as shown in Figure 9, capable of remotely transmitting the active weight to a local computer. This would allow for the real-time display of the current weight of the organic waste in the dumpster and would also allow for the continuous tracking and recording of the history of the quantities of waste collected. The use of four smaller weigh scales as opposed to one large weigh scale, while more involved of a task to set up initially, provides the advantage of being able to reconfigure the layout of the storage room much easier and to re-use these same four weigh scales with dumpsters which are a much larger or much smaller size if so desired. Each weigh scale would cost approximately $500.00 as sourced from Thames Side, totalling around $3500 for all weigh scales, the installation process and a data acquisition system. Additionally, the current dumpsters could be reused in the new SUB reducing the environmental impact, and the initial cost in the accounting system. The use of the below mechanical Schaefer-lifters allows for easy emptying of the Schaefer bins. Notice that throughout this entire process, the custodial staffs was never required to perform any lifting, simply opening of a cabinet and rolling of the Schaefer bins.

Figure 8 - Typical UBC Dumpster (USA Dumpster Rental).

Image sourced from http://www.usadumpsterrental.net/?page_id=12

Figure 9 - T20 Industrial Load Cell (Thames Side).

Image sourced from http://www.thames-side.com/load-cell-data/loadcells-t20.php)

End Life Accounting

The end of the lifecycle accounting process essentially weighs truck as they enter and leave the new SUB. This accounts for all waste products as they are transported away from the new building. One of the major advantages of this process is the ability to accommodate both UBC and third party vehicles. One major downside of the outdoor scale is that it requires a large area approximately 35 feet by 10 feet to be reserved purely for vehicle weighing. Additionally the initial instillation and capital cost would be over $10,000 based on ten load cells at $500.00 each and the metal superstructure that would be the scale deck, as shown in Figure 10.

Figure 10 - Truck Weigh Scale (How Stuff Works).

Image sourced from http://science.howstuffworks.com/engineering/civil/question626.htm

4.3 RECOMMENDATION

After considering the positive and negative social, economic and environmental aspects of each quantification method, it was observed that the industrial image as well as the capital cost of an industrial truck scale was unreasonable. As well, the idea of individual scales in each Schaefer cart was infeasible because of the maintenance costs. Finally, upon considering both the hydraulic arms and the weighed dumpster, one concept rose to the top as clearly superior. The lifting arms reduced the risk of worker injury but didn't provide the benefit of historical tracking. However, this benefit was recognized in the use of independent weigh scales beneath each corner of the dumpster. When used in conjunction with the specified mechanical Schaefer cart lifters as shown in Figure 11, the risk of employee back injury through lifting could also be avoided. This allows the current dumpsters to be reused, as well as integrate the quantification solution with the ideal rolling unit transportation method. The final solution, including a hydraulic lifter, weigh scales, installation, and a weigh scale data acquisition system would be approximately $6645.00 as broken down in Table 1.

In each of the weigh scale concepts, any data acquisition system could be implemented. One recommended solution would be using a simple LabView recording system. However, there are many additional systems available. The acquisition system cost in Table 1 is estimated from the most economic LabView option available, simply a one channel acquisition stream as sourced from National Instruments.

Table 1 - Recommended Solution Final Costs

Load cell cost sourced from http://www.usadumpsterrental.net/?page_id=12

Data acquisition cost sourced from http://www.ni.com/labview/

Item	Cost/Unit	Total Cost
Load Cells	$500.00	$2000.00
Hydraulic Lifting System	$3,495.00	$3,495.00
Data Acquisition	$1000.00	$1000.00
Load Cell Installation	$40/hr	$150.00

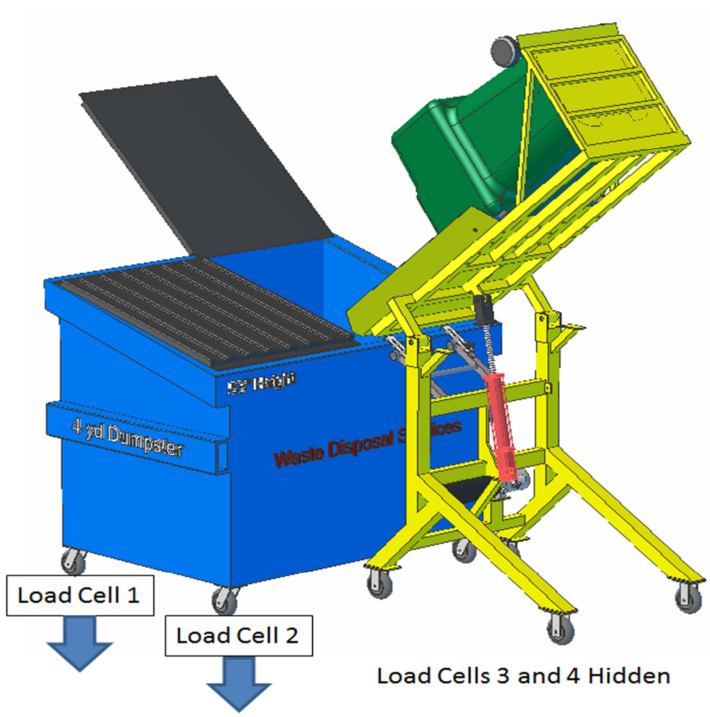

Figure 11- Combined Waste Disposal System (Ergodynamics).

Image sourced from http://www.ergodynamics.net/waste-handling

5.0 INORGANIC QUANTIFICATION AND STORAGE

5.1 CONSIDERED CONCEPTS

All of the beginning, mid, and end lifecycle organic waste quantification methods were equally applicable to inorganic waste as well. However, it was the means of storage where we recognized an improvement which could easily be tied into our accounting solution. There is value recognized in reducing the volume of inorganic waste by storing it in a compactor as opposed to a dumpster.

5.2 CONSIDERATIONS FOR EACH CONCEPT

By compressing the inorganic waste in a compacter, larger quantities can be collected and a longer period of time between scheduled pickups and transportation to the Delta Landfill can be arranged. From an environmental aspect this is advantageous because reducing the pickup frequency correlates directly to a reduction in the consumption of fossil fuels.

Since all of the accounting methods considered for organic waste are equally applicable for inorganic waste, all the same considerations apply for each concept. However, an additional consideration that must be taken into account for the use of weigh scales beneath each corner of the compactor is the increased weight. Since the inorganic wastes are being compacted, the density is thus increasing, and while a comparable volume of weight will be collected, the higher density will correlate to a higher weight. This is why it was important to consider the implementation of a compacter at this stage, so as to ensure that if required, a weigh scale rated for a higher weight specified.

5.3 RECOMMENDATION

Similarly to the organic waste, the recommended solution is to implement a compactor such as that shown in Figure 12, which would also rest upon four weigh scales, one beneath each corner. These weigh scales utilize the same load cells capable of remotely relaying the total weight of the compactor to the software unit which can again both display and record the history of the weight of the inorganic waste collected.

Figure 12 – 6:1 Compaction Ratio Inorganic Waste Compactor (CompactorGuy Products).
Image sourced from

http://www.thecompactorguy.com/index.cfm?fuseaction=article&ArticleID=78&section_id=4

6.0 CONCLUSION AND SUMMARY OF RECOMMENDATIONS

It is recommended that the new SUB adopt a waste accounting program which is composed of the following steps:

1. Waste is sorted by offering the occupants of the SUB specifically labelled receptacles for different types of waste. These receptacles are wooden cabinets which house the common Schaefer carts currently used in the SUB. The labels on the cabinets are not of the type of waste collected, but of the final destination of that type of waste.
2. The Schaefer bins can be wheeled by employees to the waste storage room in the SUB where mechanical Schaefer bin lifters are available to lift and dump the Schaefer bins into larger storage receptacles.
3. In the case of the organic waste, the larger receptacle is dumpster which will hold the organic waste until such times as it is picked up for transportation to the UBC compost digester. In the case of the inorganic waste, the larger receptacle is a compacter which will compress the inorganic waste allowing for longer time before scheduled picked and delivery to the Delta Landfill.
4. It is during this mid-lifecycle holding stage that the accounting of the waste will take place. This is done through the use of four weigh scales per dumpster or compactor, one beneath each corner. Each weigh scale is comprised of a load cell which is capable of remotely relaying the weight of the dumpster or compactor to a computer which is able to display the weight as well as track and record the history of the quantities of each type of waste collected.
5. The information collected can then be used to determine the ideal pickup frequency for each type of waste, optimizing the pickup frequency for maximum time between pickups.

From a triple bottom line assessment, this integrated process represents the ideal way to implement a solid waste accounting system in the new SUB because it contains the following social, environmental, and economic benefits:

Social:

- Labelled wooden cabinets induce a sense of local awareness to the individual disposing of the trash item as where that item will ultimately end up.
- Sorting of types of waste between organic and inorganic during disposal eliminates the undesirable task of having to manually sort the types of waste, thereby eliminating the risk of hand injuries by hazardous materials.
- Use of existing Schaefer carts allows for easy operations to be carried out by custodial personnel in terms of ergonomics of rolling versus lifting, eliminating back strains and other related injuries.
- Use of Schaefer carts instead of automated systems such as conveyors or trash chutes maintains existing jobs and employment for custodial personnel.

Environmental:

- Creating a sense of local awareness in occupants of the SUB will promote responsible waste disposal decisions, resulting in a higher rates of compost and recycling and lower rates of landfill wastes.
- The reuse of existing Schaefer carts in conjunction with the purchase of additional Schaefer carts produced of recycled plastics minimizes the environmental footprint of the new SUB's waste management system as whole.
- The use of the compactor to reduce the volume of the collected inorganic waste maximizes time between scheduled pickups and deliveries to the landfill which minimizes the consumption of fossil fuels and thus toxins released to the atmosphere.
- Tracking of the history of the quantities of each type of waste produced allows to easily monitor the progress towards UBC's zero-waste initiative.

Economic:

- Among the cheapest of all concepts considered.
- Tracking the history of the quantities of each type of waste collected can be used to predict future quantities and allow for better informed purchasing decisions when upgrading or replacing facilities such as Schaefer cart.

APPENDIX A: REFERENCES

MJ Waste Solution (April 22, 2010). Student Union Building Phase 2 Waste Audit Results and Waste Management Plan.

This waste audit prepared by MJ Waste Solutions at the Student Union Building at the University of British Columbia was extremely useful in providing insight into the types of sanitary issues that arise through inadequate waste management practices.

Mayfran International (January, 2012). Mayfran International Recycling and Solid Waste Conveyor Solutions. Retrieved November 3rd, 2012 from http://www.mayfran.com/applications/industry/recycling_and_solid_waste

This source was very informative in terms of providing information regarding conveyor systems used in industry. It primarily aided in the understanding of the preliminary requirements of conveyor systems before installation can occur as well as required maintenance operations.

Bamonti, S., Bonoli, A., & Tondelli, S. (2011). Sustainable waste management criteria for local urban plans. *Procedia Engineering,* 21, 221-228.

This paper by Bamonti et al. addresses the practical side of implementing a waste management system in local urban plans. Its significance comes not from the specific data, but more from the common challenges when implementing a divided waste collection system consisting of different types of waste such as organic, inorganic and recyclable. This overview will give us insight and hopefully identifies many of the common initial challenges.

BigBelly Solar. (June 2009). City of Philadelphia case study: Cost-savings from solar-powered compactors for trash and recycling. Retrieved October 15, 2012 from http://bigbellysolar.com/files/CaseStudy-Phila-Full-06-09.pdf

This document was very useful in providing insight into the cost savings that can be incurred by reducing the collection frequency of inorganic solid wastes destined for landfill. Not only is there a financial benefit recognized, but there is also an environmental benefit in the reduction of total time required for collection vehicles to be on the road, ultimately resulting in decreased fossil fuels emissions.

Chen, H.-W., Chang, N.-B., Chen, J.-C., & Tsai, S.-J. (2010). Environmental performance evaluation of large-scale municipal solid waste incinerators using data envelopment analysis. *Waste management*, 30(7), 1371-81.Elsevier Ltd.

This paper by Chen et al. outlines the positives and negatives behind industrial incinerators for waste management. The journal article looks at the secondary pollution, cost effectiveness, and operational efficiencies involved with the use of an incinerator. The idea of alternative processes such as incineration are often overlooked when institutions are concerned about maintaining a green image; this paper looks at the practical application of incinerators and analyzes overall environmental benefits allowing for the removal of the current market bias and provides holistic consideration of this waste management method.

Igbinomwanhia, D. I., & Alao, N. J. (2011). Integrated solid waste management system – A case study of solid waste source sorting alternative in a tertiary institution in Nigeria. *Advanced Materials Research,* 367, 807-814.

This study outlines the importance of sorting solid wastes in regards to overall reduction and management. This article provides an overview and critical data regarding which demographics such as academic staff, non-academic staff or students, followed the upfront waste bin sorting methods and how this related to overall management efficiencies. This article provides key information regarding the general trends of an academic institution and which populations are more or less likely to follow sorting suggestions and by how much.

Macy, J. (2010). San Francisco zero waste policies & programs zero waste for sustainability. Retrieved October 21, 2012 from http://www.csgeast.org/policy/documents/Macy_SanFranciscoZeroWastePoliciesandPrograms_11-29-11_000.pdf

The primary argument behind Jack Macy's Zero Waste Policies and Programs presentations is that the first starting point behind waste management is the need for reduction to start on an individual level, and this small change will greatly improve environmental and sociological impact. The major benefit behind this presentation is the robust mobile storage containers that are used to separate recyclables, food scraps and numerous other categories, or, in our case, inorganic and organic wastes.

North Sidney Council. Waste handling guide. Retrieved October 25, 2012 from http://www.northsydney.nsw.gov.au/resources/documents/Waste_Handling_Guide.pdf

This guide from Sidney, Australia gives important information for the design of waste handling facilities. It was especially important to the development of our ideas about the storage room, which has to be designed so that cleaning and garbage collection are facilitated. This guide also drew our attention to the fact that for the design for this type of facility, governmental hygiene standards and regulations must be followed.

Schwartz, M. (2011, October 14). Arizona State University excels as sustainable campus. Retrieved October 28, 2012 from https://asunews.asu.edu/20111014_sustainablecampus

This new article outlines the advances of Arizona State University which is among the top 25 greenest college campuses in the United States. The significance of this article is that it outlines the requirements to attain a truly integrated sustainability system. Similar separation and sorting methods for inorganic and organic wastes could also be applied to our project within the Student Union Building with slight modifications to fit our specific application.

Shao, H. (2010). The construction of management system model for environmental assessment of solid waste. *2010 IEEE International Conference on Intelligent Computing and Intelligent Systems,* 351-355.

This paper looks at the triple bottom line assessment regarding solid waste management and the different alternatives to track waste. The value in this paper comes from its definition of the general lifecycle of waste, and it identifies common issues that arise in waste management systems. For each of the identified issues, it proposes a solution model.

Skordilis, a. (2004). Modelling of integrated solid waste management systems in an island. *Resources, Conservation and Recycling,* 41(3), 243-254.

This paper outlines the implementation of a solid waste accounting system in a high traffic closed island setting. The journal article is very applicable as the high traffic island is similar to that of the isolated Student Union Building experiencing foot traffic from all aspects of the university and depositing their waste within. The goal is to draw from the implementation of their socially, economically and environmentally sound system for our new SUB waste management. This journal article also touches on the environmental, financial, technical and social criteria regarding implementation in a tourist environment which could provide some insight into the waste behaviour of visitors to the campus who enter the Student Union Building.

Slagstad, H., & Brattebø, H. (2012). LCA for household waste management when planning a new urban settlement. *Waste Management* (New York, N.Y.), 32(7), 1482-90. Elsevier Ltd.

This paper addresses waste management and life cycle assessments specifically related to new urban developments. It looks at the possibility of alternative collection cycles and the resulting impact on carbon emissions. This is very useful for our project because it analyzes differences in carbon emissions where waste sorting is performed locally through increased recycling as well as through simple reduction.

Wiley, A. (2012, September 11). Berea College using the sun to compact trash. Retrieved October 3, 2012 from http://bcnow.berea.edu/2012/09/berea-college-using-the-sun-to-compact-trash/

This report was found while we were investigating the efforts of other institutions in terms of zero waste projects. Berea College has implemented solar-powered compactors primarily to reduce to total volume of waste produced and thus also to collection frequency ultimately resulting in reduced fossil fuel emissions. These compactors also allow for data collection to better understand and quantify the amount of waste being disposed of.

Zhang, N., Williams, I. D., Kemp, S., & Smith, N. F. (2011). Greening academia: developing sustainable waste management at Higher Education Institutions. *Waste management* (New York, N.Y.), 31(7), 1606-16. Elsevier Ltd.

This paper outlines the practical implementation of waste management systems in higher level or university level educational institutions. This will provides excellent information on the Student Union Building because it outlines different university strategies to convey management or recycling techniques, many of which could easily be implemented with our project.