BEYOND 70%: ASSESSING ALTERNATIVE WASTE MANAGEMENT OPPORTUNITIES FOR INSTITUTIONS

by

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DALHOUSIE UNIVERSITY

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This thesis is dedicated to my parents. For their love, endless support, and encouragement.

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ABSTRACT

Initial investigations into the waste management practices at Dalhousie University revealed opportunities for more effective and efficient management of the four major waste streams. However, there was no comprehensive framework in place to properly evaluate which of these opportunities is most appropriate. Neither was there a model system in use at other institutions that could be easily applied to the Dalhousie context. The purpose of this research was to address this issue and, in doing so, to provide a framework for Dalhousie University for facilitating the selection of stakeholder-inclusive waste management options. The study applies a multi-criteria decision analysis (MCDA)/weighted sum model (WSM) framework to waste management decision-making within an institutional setting. Interviews and focus groups were conducted with key stakeholders selected based on their knowledge and experience in waste management, as well their position or role. The knowledge and expertise from the stakeholders was elicited and used to inform the development of twelve evaluation criteria for assessing three waste management options, as well as the weightings used in the analysis. The outcome of this research demonstrates a novel approach for implementing a framework that other organizations and institutions can apply to facilitate the selection of waste management options.

LIST OF ABBREVIATIONS USED

AC	Agricultural College
BAU	Business as usual
CCME	Canadian Council of Ministers of the Environment
DM	Decision maker
GHGs	Green house gases
HEI	Higher education institution
HRM	Halifax Regional Municipality
IC&I	Institutional, commercial, and industrial
MCDA	Multi-criteria decision analysis
MRF	Materials recovery facility
RRFB	Resource Recovery Fund Board
SWM	Solid waste management
TPD	Tonnes per day
UNEP	United Nations Environmental Programme
WSM	Weighted sum model

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CHAPTER 1 INTRODUCTION

1.1 Problem Statement

Organizations and businesses in the industrial, commercial, and institutional (IC&I) sector face many waste management challenges. According to the United Nations Environmental Programme (UNEP) (2009):

> "The inability to fully grasp the problems of waste generation and characterization have resulted in transforming Solid Waste Management (SWM) as one of the most compelling problems of urban environmental degradation" (p.21).

This sentiment is echoed by Smyth *et al.,* (2010), who report, "comprehensive SWM programs are one of the greatest challenges to achieving institutional sustainability" (p. 1007). The promotion of waste management planning to combat some of these challenges is becoming more common throughout the world, especially in North America (Allwood *et al,* 2010).

In 2011, the Government of Nova Scotia released "Our Path Forward: Building on the Success of Nova Scotia's Solid Waste Resource Management Strategy." This plan was designed to strengthen relationships with key stakeholders and help the Province achieve an annual waste disposal target of 300 kilograms or less per person by 2015 (Government of Nova Scotia, 2011). In order for the province to reach such a target, it will be imperative for Nova Scotian institutions to actively support such an agenda. To do so, these institutions and related organizations will need to have comprehensive waste management systems in place.

Developing such a framework involves the integration of three separate elements. First, an assessment of an institution's current waste management practices and strategies provides insights regarding the opportunities and challenges associated with existing waste streams. Secondly, an understanding of the various waste disposal and diversion options helps to determine what type of waste management practices and technologies are best suited for an institution's diverse material streams. Finally, the integration of views, ideas and expertise from the various stakeholders involved with the institution's waste management operation helps provide important information about the feasibility and acceptability of the options and strategies put forth.

Many institutions typically employ waste management activities, specifically recycling, as a lead into sustainability initiatives (Mason *et al.,* 2003; Zhang, 2011). For example, the University of Calgary (2012) has developed a recycling and waste management plan that "encompasses all recycling and waste streams on campus in order to achieve the university's strategic goal of achieving zero waste" (para. 1). This was accomplished by designating a single department to oversee all the diversion programs so that any redundancies in waste programs were eliminated.

When developing a comprehensive waste management plan, institutions face a variety of options. The options available for waste disposal, for example, will differ depending on the characteristics of the material stream, the source of the waste being generated, and the operational stages that exist in the existing waste management process (i.e., collection, transportation, processing, and disposal). In the past, waste management options were evaluated and selected largely on the basis of their cost effectiveness (Powell, 1996). However, with the increasing paradigm shift towards responsible management, it is no longer deemed appropriate for decision makers to base their decisions strictly on monetary costs and economic indicators (Edwards, 2005). In recent years, evaluation has involved a more holistic approach that incorporates not only economic criteria but also environmental, social, and health-related factors into the decision making process (Chung and Poon, 1996; Dale and English, 1999; Herath and Prato, 2006; Ahn and Choi, 2012).

According to Smyth *et al.* (2010), much is reported on waste management plans at the municipal level (Zeng *et al.,* 2005; Parizeau *et al.,* 2006; Hung *et al.,* 2007; Hristovski *et al.,* 2007; Chang and Davila, 2008; Gomez *et al.,* 2009; Bovea *et al.,* 2010 and Phillips & Brown, 2010). However, few waste studies have been conducted at the institutional level (Farmer *et al.,* 1997; Dowie *et al.,* 1998; Dursun *et al.,* 2011). There have only been a handful of studies conducted at Higher education institutions (HEIs) that explore and assess an institution's current waste management practices and potential management alternatives (Mason *et al.,* 2003; Armijo de Vega *et al.,* 2008; Zhang *et al.,* 2011).

Like many other institutions, Dalhousie University, in Halifax, Canada currently does not have a comprehensive waste management plan based on detailed option analysis. Initial investigations into the waste management practices at Dalhousie University revealed opportunities for more effective and efficient waste management of the four major waste streams: paper/cardboard, or 'fibre'; recyclables; organics; and garbage. However, there is no comprehensive framework in place to properly evaluate which of these opportunities was most appropriate, nor was there a model system in use at other institutions that could be easily applied to Dalhousie.

1.2 Research Purpose

The purpose of this research is to provide a decision-making framework for Dalhousie University that is stakeholder-inclusive and facilitates the selection of waste management options. To achieve this, the following objectives were set:

1.3 Research Objectives

- To examine Dalhousie University's current SWM practices, including the characterization of the fibre, recyclables, organics, and garbage materials streams.
- To apply a multi-criteria decision analysis (MCDA) framework that would aid Dalhousie mangers in determining and evaluating alternatives most appropriate within the Dalhousie, Halifax Regional Municipality (HRM), and Nova Scotia context.

1.4 Study Area, Scope, and Research Outcomes

Dalhousie University is located in Halifax Nova Scotia, Canada and is the largest institution of higher learning in the Maritime Provinces. The university consists of four campuses, three of which (Studley, Carleton, and Sexton) are located in Halifax while the Agriculture campus is located in Truro, Nova Scotia. The three Halifax campuses are spread across the south end of the city, occupying more than 32 hectares of land and approximately 1.7 million square meters of building space. In 2010, Dalhousie's Office of Sustainability released its sustainability plan for the university, in which it outlined a goal of achieving a waste diversion rate of 70% or greater by 2020. Because the university's focus on sustainability requires consideration of factors beyond cost, multiple dimensions will need to be included in the decision making process.

Research into specific attitudes of stakeholders towards current and future waste management practices at the university is crucial in assisting the development and implementation of a waste management system. The MCDA model supports a decision making process that is stakeholder-inclusive and uniquely appropriate to the Dalhousie, HRM, and Nova Scotia context. The development of the decision model considers factors primarily related to the operational management process within Dalhousie, such as the collection (handling), transportation, processing, and disposal stages of waste management for the fibre, recyclables, organics, and garbage streams. Procurement issues as they relate to waste management (e.g. changing purchasing decisions that could influence waste production) are not incorporated into this research due to project time constraints and the breadth of the subject matter.

An investigation into these research objectives requires an understanding of the university's current waste management practices, characterization of its waste streams and knowledge regarding the feasibility of employing different technologies for processing those streams. This requires input from those that operate within the relevant systems, including individuals internal to Dalhousie as well as external stakeholders involved in the regulation and operation of the waste management supply-chain. This includes, but is not limited to Dalhousie professors, custodial and management staff, as well as representatives from the HRM Solid Waste Resources Division, Resource Recovery Fund Board (RRFB), university and college institutions other than Dalhousie, Scotia Recycling Limited, and Nova Scotia Department of the Environment. This research:

- Leads to a better understanding of Dalhousie's current waste management system;
- Identifies new alternatives for waste disposal and management options that the university could potentially adopt; and,
- Provides other institutions with a stakeholder-inclusive framework for facilitating the selection of waste management options within an institutional setting.

1.5 Outline of Thesis

Chapter two examines the literature on waste management and MCDA. It also provides background information regarding waste management at Dalhousie--the major streams on campus and the potential on-site and off-site processing considerations for these streams. Chapter three is an overview of the mixed-method approach used in this research. Chapter four highlights the results of the waste stream characterization at Dalhousie, the key informant considerations, and current and future costs for different waste management considerations on campus. Empirical data, related to the specific views of various stakeholders and regarding the types of options that should be considered appropriate for further evaluation, are presented. This chapter also presents the results of the interviews and focus groups, as well as the outputs of the MCDA and WSM framework.

Chapter five discusses the importance of conducting a document review and auditing service invoices, the importance of stakeholder engagement, and the importance of waste management education. This chapter also discusses in detail the stakeholder approach and application of a MCDA framework for Dalhousie University as a means to evaluate the various options available to Dalhousie for the management of the different material streams. A discussion is provided on the outcomes and research implications, as well as contribution to scholarship. This chapter also provides a discussion of how the applied

MCDA framework, integrated with the WSM, could support the development of a similar management evaluation process in other institutional settings. Chapter six concludes the thesis by recapping the major findings of the research, suggesting areas for further study, and discussing the limitations of the research.

CHAPTER 2 BACKGROUND AND LITERATURE REVIEW

2.1 Waste Management in Nova Scotia

Nova Scotia has become a North American leader in (SWM) practices, and was the first and only province to achieve Canada's 1989 national goal of diverting 50% of the nation's municipal solid waste from landfills by 2000 (Wagner and Arnold, 2008). In 1990, the Province embarked on a strategy for managing municipal solid waste. The result was a comprehensive province-wide 'Solid Waste Resource Management Strategy' that focused heavily on pollution prevention as a means to meet the nation's diversion target goal (Wagner and Arnold, 2008). Nova Scotia currently boasts one of the highest waste diversion rates in Canada (Government of Nova Scotia, 2011).

Nova Scotia's updated waste management plan, 'Our Path Forward', consists of six major province-wide goals: to increase participation in waste prevention and diversion programs; to improve compliance and waste education programs; to increase waste diversion; to increase cost effectiveness of diversion programs; to increase producer responsibility of end-of-life management of products and materials; and, to increase diversion of construction and demolition waste being generated from onsite projects (Government of Nova Scotia, 2011). Over 160 individuals representing a variety of stakeholders came together to help formulate these goals. Considered to be a critical component of the 1995 waste strategy, mandatory participation in waste diversion initiatives and programs is just as important now (Wagner and Arnold, 2008) . Of particular importance are the IC&I sectors, which will need to be more actively involved in these initiatives and programs if the province's goals are to be reached. If those in such sectors (e.g., institutions such as Dalhousie) are to support the strategic goals of the province, they must first create their own waste management strategies that are tailored to fit the specific needs of the institution.

2.2 Waste Management at the Institutional Level

Waste management broadly refers to the processes involved in collecting, storing, transporting, treating, processing, monitoring, and disposal of waste materials, as well as recovery of resources from waste, and the facilities required for such activities (Jennings and Sneed, 1996). The waste hierarchy associated with managing materials waste can be summarized with the three Rs, reduce, reuse, recycle, with waste reduction being the most desirable or highly prioritized (Goddard 1995; CCME 1996; Fournier, 2008). Disposal (land filling or incineration) is considered the least desirable (Goddard 1995; CCME 1996; Fournier, 2008). This hierarchy is intended to form the foundation of sustainable waste management practices (Zhang, 2011), providing a structured order for the preference of waste management options based on environmental impact (DEFRA, 2002). Waste materials requiring management can include solid, liquid, gaseous, radioactive and hazardous substances. These materials are often generated in large volumes: non-residential sources were responsible for approximately 58% of total waste disposal in Nova Scotia during 2008 (Statistics Canada, 2010), and large institutions are major contributors to municipal solid waste generation (Allan *et al.,* 2010).

Being centers of learning and research, and providers of cultural, recreational, and infrastructural resources (Lambert 2003; Zhang *et al*., 2011), universities and colleges have always played a critical role in pushing science forward within society (Stephens *et al*., 2008). They have a tremendous potential to mobilize and drive society's transition towards sustainability (Stephens, 2008) and are both morally and ethically obliged to act responsibly towards the environment and to set an example for students and communities to follow (Armijo de Vega *et al.,* 2008, p. S22). Considering these important roles in society, HEIs should be among the top leaders in sustainability, at the forefront of environmental protection and responsibility relating to sustainable activities (Armijo de Vega *et al.,* 2008; Zhang *et al.,* 2011).

Effective waste management plans represent an essential part of reaching sustainability-related policy goals and targets. To be effective, an institution's waste management strategy must be developed around empirical data—the kind of data that emerges from carefully conducted waste characterization studies. Such studies provide insight into organizations' specific waste material streams (characterization) and the related quantities that need to be managed (Smith and Scott, 2005; Armijo de Vega *et al.,* 2008). Proper planning and implementation of a well-defined, comprehensive waste management program–one that takes into account measures to "prevent" and "recycle" waste–minimizes the negative issues associated with waste generation and disposal (EPA, 2002).

Many institutions typically employ waste management strategies, such as recycling, as a first step towards more extensive sustainability initiatives (Mason *et al.,* 2003; Zhang, 2011). Recycling programs and related waste management initiatives are often difficult to establish within institutions; the formation and subsequent success of a waste management plan depends on (UC Davis, n.d.; Creighton, 1998; Armijo de Vega *et al.,* 2008; Evangelinos *et al.,* 2009; Kaplowitz *et al.,* 2009; and Zhang, 2011; Zhang *et al.,* 2011):

- the support and commitment from the institution's senior administrative officials towards waste management projects;
- an understanding of the institution's current waste management practices and infrastructure, including the roles of key stakeholders;
- adequate funding;
- having an internal recycling/ waste coordinator and committee to oversee waste management initiatives;
- strong communication between the various people involved in implementing the plan and senior administrative staff;
- community engagement and support;
- reliable external waste service haulers that provide accurate weights of waste removed; and

- a true understanding of the feasibility of the potential waste management alternatives.

Research from other HEIs indicates that appointing a recycling and waste coordinator can improve the effectiveness of an institution's waste management plan and lead to increased landfill diversion rates (UC Davis, n.d.; Kaplan, 2008; Fournier, 2008; Zhang, 2011). These coordinators effectively oversee activities such as: monitoring and ensuring legal compliance, assisting in the development of sustainable procurement policies, preparing/ managing related budgets, and providing training and education to staff and students.

Existing (or potential) operational logistics represent another important factor to be addressed by a comprehensive waste management plan. According to UC Davis (n.d.) and the Canadian Council of Ministers of the Environment (CCME, 1996), key components include the type of equipment required, current collection and storage practices, the stages involved in the waste management process, and the human resources needed. This should also include an understanding of the current contracts with external waste services and material use. The human resources component is particularly important to the overall success of a waste management plan as it relies upon the co-operation of different stakeholder groups (UC Davis, n.d.). Exploring the attitudes of key stakeholders can lead to a better understanding of current practices and of the feasibility of various alternatives. For example, according to Schübeler *et al.* (1996), custodial staff, as those who are responsible for collecting waste from indoor bins and transporting it to a centralized location, can play an active role in waste management systems. Custodians are usually particularly aware of problematic issues and can be helpful when re-organizing collection locations and schedules. As another example, municipal waste representatives can provide valuable feedback and advice when examining different management alternatives. They are capable of sharing educational resources, helping to develop educational plans, and providing information regarding which kinds of services are required from particular waste service providers (Davidson, 2011).

Finally, the institution's management executive should also be included in the developmental process. This includes managers, administrators and/ or directors of the various departments within an institution (finance, facilities management, procurement, etc.) that could influence operational procedures or program implementation (UC Davis, n.d.).

Most institutions, including HEIs, will continue to require services provided by commercial or 'third party' waste service contractors (Davidson, 2011) and, in this case, it is imperative that an appropriate waste disposal agreement is negotiated (Creighton, 1998). An agreement should specify items such as, "who will haul the trash from the campus, how it will be measured, and how much its disposal will cost" (Creighton, 1998, p.54). Another important item that should be considered when agreeing to a waste disposal contract with a commercial waste service provider is related to tipping fees. Tipping fees should be based on accurate and frequent reporting of waste weights/ volumes rather than estimations (Creighton, 1998). Adequate research into the institution's waste management needs at different operational stages can lead to successful and beneficial contracts with waste service providers.

2.3 Waste Management Operational Stages

There are typically five stages to waste management: procurement, collection (handling), transportation, processing, and disposal (Tchobanoglous and Kreith 2002; Wanless Enviro Services, 2008). The following section will look at each of these stages.

Procurement

Procurement of goods and services is not within the scope of this research, primarily because of time constraints and the breadth of the topic. Information regarding long term purchasing trends can be identified through a thorough examination of an organization's purchasing practices (UC Davis, n.d.). It is important that the personnel responsible for procurement are aware of waste reduction policies and initiatives, as they will be in a position to impact purchasing decisions for the entire university (Hignite, 2008). If there is no central procurement policy in place, individual departments need to be aware of the university's sustainability mandate, waste reduction goals, and any other pertinent waste reduction policies and initiatives. This information should inform their purchasing decision with the aim of replacing environmentally damaging or non-recyclable materials with those that are more environmentally benign (UC Davis, n.d.).

Collection (handling)

The collection stage plays an important role in the overall sustainability and effectiveness of a waste management plan. This stage refers to the gathering of solid wastes and recyclable materials from an institution's various on-site locations (Tchobanoglous and Kreith, 2002). Individuals who frequent the institution's grounds and facilities must be provided with easy access to waste collection receptacles, both indoors and outdoors. Similarly, external waste service providers must be able to collect and remove waste from an institution's property in a manner that is convenient for both parties (McDougall *et al.,* 2001). High traffic areas and areas of congregation (e.g., atriums, building entrances and quads) should contain source separation stations for all the major streams on campus. Waste receptacle locations need to be accessible to collection carts as well as to the general public. Areas for storage also need to be in compliance with health, safety, and fire regulations (Davidson, 2011).

Centralized consolidation points are designated locations within a building or on different areas of campus where custodial staff have an agreed upon point to drop off waste that has been collected from a building (UC Davis, n.d.; Hill, personal communication, March 2012). From these points, material is collected and transported to a central storage facility on campus for further processing and disposal. The centralized storage area should be able to store a significant amount of material, reducing how often bins need to be serviced and (Bickford, 1995) and thereby reducing costs at the transportation stage.

Transportation

The first step involved in this stage is the transfer of wastes from designated holding areas and smaller collection vehicles to larger transport equipment or storage areas. The second step refers to the transport of the various waste materials to the appropriate processing or disposal sites (Tchobanoglous and Kreith 2002). For example, the transport of solid waste to off-site processing and disposal facilities is generally done by an external waste hauling company using roll off and front end loading containers (UC Davis, n.d). Front end loading containers for the solid waste stream, commonly referred to as dumpsters, range from 2 to 8 cubic yards in capacity and are serviced by external waste haulers. Front end loading containers present a greater challenge when it comes to tracking specifics compared to services that use roll off containers. Determining the weight of individual front end loading bins is not possible unless the collection vehicle is equipped with an on board scale at the time of hauling (UC Davis, n.d.).

Unlike front end loading disposal containers, billing involved with roll off containers is tracked using weights and hauling fees. It is important that a transparent billing process is established, with external waste haulers providing the institution with copies of scale slips and transport work orders with monthly billing statements (UC Davis, n.d.; Wipe Out Waste Construction, 2011.)

Processing

Processing refers to the facilities used for the recovery of waste materials that have been separated at the source (Tchobanoglous and Kreith 2002). Processing of materials can either be done on-site or off-site depending mainly on campus size, space availability, operating budget, and the material involved. If the space available on campus to process waste materials is insufficient, it is the institution's responsibility to arrange for a processing facility capable of handling the material (UC Davis, n.d.). In some cases, campus vendors, such as food vendors, may be held accountable for providing the necessary means to have materials processed. The university can stipulate to vendors and external waste service providers to transport materials from the recycling stream to off-site material recovery facilities (MRFs), which are used for front end sorting, processing and storage of recyclable materials (Recycling Marketing Cooperative for Tennessee, 2003). If materials are being transported elsewhere for processing, the university is entitled to know where the material is being delivered or marketed. Processing equipment, such as balers and densifiers, can be used to significantly reduce the space required to store materials on-site (CCME, 1996), increasing the overall efficiency of an institution's waste management system.

Disposal

The disposal stage refers to the solid waste that has been collected and transported to a disposal site, typically a landfill, either directly from an institution or as residual materials from MRFs and composting facilities (Tchobanoglous and Kreith 2002). Non-recyclable materials are disposed of in landfills, whereas recyclable materials are sent to facilities where they are processed into raw materials to be packaged and sold again as value-added products. The disposal stage of waste management often involves costs (i.e. landfill tipping fees), as most institutions do not have the means to dispose of materials on their own. Disposal costs can be reduced through increasing recycling efforts via program creation (UC Davis, n.d.). It is important to note that, when considering opportunities for both waste reduction and diversion, special attention should be paid to the organics stream because of the high economic and environmental costs associated with inappropriate disposal (Tammemagi, 1999; Smyth *et al.,* 2010).

Understanding an institution's operational stages and how the different waste materials are dealt with at each stage is necessary for the development and implementation of a waste management strategy. When developing potential alternatives, each option should be examined in the context of the institution's various operational stages for the major waste streams.

This study into Dalhousie's waste activities analyzes each of the above operational stages for each of the four major waste streams at Dalhousie University in an attempt to thoroughly evaluate the potential opportunities for sustainable waste management practices.

2.4 Waste Management at Dalhousie University

Dalhousie University has four campuses, three in downtown Halifax with over 93% of the population and one campus in a rural location 100 km from the Halifax campuses. The University is over to over 26,000 students and employees. As of 2011, 2,345 of those people were on-campus residents at the Halifax campuses. Not included in these figures is the total number of visitors from the general public who often frequent university grounds throughout the year. Generators of waste on campus can be grouped into three broad categories: students, employees, and the general public.

2.4.1 Waste Generators

Knowing the contributing sources to an institution's on-site waste generation is important in designing education programs and moving forward with a formal waste strategy that can be tailored to the institution's waste generation (Ennis, 2012). Students who attend Dalhousie University come not only from across Canada but also from many other countries, and may be unaware of the province's waste and recycling practices. This often represents a major obstacle in obtaining higher diversion rates: if students are unfamiliar with particular waste materials and unable to identify the correct collection bin for waste disposal, contamination of the waste stream is likely to occur.

HEIs are presented with the challenge of having to deal with a constant influx of new students each year. According to Green Networld (2001), the average university or college student in North America produces approximately 290 kilograms of solid waste per year, including 500 disposable cups and about 145 kilograms of paper. Moreover, an average size university can throw out about 1000 kilograms of food per day (Creighton 1998).

University employees are also responsible for creating waste on campus. There are approximately 7,800 full-time, part-time, casual, and contract people employed by Dalhousie University (Owen, personal communication, January 2011).

With such a large number employees, waste programs and initiatives (e.g., the waste bin exchange program and the waste management-learning module) become important tools for educating employees and promoting sustainable waste management practices. Participation in such events is needed in order to fully engage the employees on the institution's waste management initiatives (Smyth *et al.,* 2010; UC Berkeley, 2011).

Lastly, the general public is another contributor to Dalhousie University's waste generation. While not as significant a contributor to the waste produced on campus as students and employees, individuals who visit the campus can still have an effect on waste stream contamination if they are not aware of the university's recycling practices and what material goes where. Proper signage and labeling, as well as effective bin placement, become important mechanisms for ensuring that source separation is done correctly by the pubic (Toronto's Solid Waste Management Services, 2011).

Dalhousie University's sustainability plan calls for a 70% or greater waste diversion by 2020. In order to help achieve this goal, the university has a number of different programs, polices, and procedures in place. For example, the university employs a multi-stream waste receptacle system to collect waste generated from each of the four major streams on campus - recyclables, paper, organics, and garbage. Dalhousie promotes the waste management hierarchy of 'rethink,' which implies the principle of purchasing to reduce waste, followed by reuse, recycle, recover, and lastly disposal (Davidson and Owen, 2011). The 'Re-think/ Reduction' programs at Dalhousie University, for example, include sustainable purchasing workshops, and a waste bin exchange whereby employees can exchange their black waste bin for a blue recycling and a mini-waste bin. While the university has designed a number of programs to address aspects of the waste hierarchy, Dalhousie does not have a formal waste management strategy in place. With the recent release of Nova Scotia's 2011 updated waste management strategy, 'Our Path Forward' (Government of Nova Scotia, 2011), it becomes imperative that the university develops and implements a waste management plan that can not only successfully achieve their target goals but also meet waste disposal goals and initiatives as outlined in the provincial waste management strategy.

2.4.2 Major Waste Streams at Dalhousie University

It is important to understand the composition of the waste materials being generated on-site (Farmer *et al.,* 1997; Smyth *et al.,* 2010). Through a number of waste audits, Dalhousie University has identified seven material streams on campus: garbage; recyclables; organics; paper/ cardboard (hereafter called fibre); hazardous waste, which is classified in the *Transportation of Dangerous Goods Regulations* and requires special disposal measures to reduce hazard (e.g. Class 1 – explosives); universal hazardous waste, which is defined as substances that cannot be processed by standard municipal waste but does not pose the same risk as hazardous wastes (e.g. CFL light bulbs); and construction and demolition waste (Davidson *et al.,* 2011). As noted, the four major waste streams–those addressed in this study–are fibre, recyclables, organics, and garbage.

<u>Fibre</u>

The fibre stream is composed primarily of paper. According to the US Environmental Protection Agency (2010), recovered fibre products with longer fibres (i.e. office paper) provide greater flexibility for recycling compared to products of shorter fibre (i.e. newspaper). As a result, fibre products with long fibres (e.g., corrugated cardboard, office paper, miscellaneous paper, and other mixed/ composite paper) sell for a higher price on the market (Davidson *et al.,* 2011).

<u>Recyclables</u>

Materials considered to be recyclable in HRM that are found on campus include plastics, metal, and glass. Thermoplastics (e.g., #1 polyethylene terephthalate, #2 high density polyethylene, # 3 poly (vinyl chloride), # 4 low density polyethylene, and # 5 polypropylene) are the more common plastics found in municipal solid waste streams and can be recycled (Siyavula, n.d.; Smith and Scott, 2005).

Metals that can be recycled in Nova Scotia include ferrous metals, aluminum, copper and other nonferrous metals (Davidson *et al.,* 2011). Glass can be recycled indefinitely because of its mixed composition of silica and sodium carbonate (Ohio Department of Natural Resources, n.d). Glass bottles are generally broken down into two categories:

refundable and non-refundable. Refundable items include soda bottles, wine and beer bottles and have to meet the criteria for refund at the recycling depot in order for a client to receive back the deposit. Non-refundable items do not meet a criteria set and include items such as mayonnaise and jam jars (Davidson *et al.,* 2011). However, this 'non-refundable' glass is still recyclable.

Beverage containers are also broken down in terms of whether or not they are refundable. According to the RRFB (2013), aluminum beverage cans, gable top beverage cartons (excluding milk, rice, and soya cartons), tetra pak beverage cartons (excluding milk, rice or soya, and milkshake cartons), plastic beverage containers (excluding milk jugs) and steel beverage cans (excluding food cans) are all considered refundable.

<u>Organics</u>

Organic waste is banned from landfills in Nova Scotia and therefore must be composted through either aerobic processes or anaerobic digestion (van der Werf, 2010). The following are examples of items included in the organics material stream at Dalhousie: food (e.g. dairy products, bread, rice, pasta, coffee grounds, egg shells, fruits and vegetable peelings); boxboard, paper towels and soiled paper; cooking oil/ grease; leaf and yard waste (Davidson *et al.,* 2011).

<u>Garbage</u>

Materials found in the garbage stream essentially encompass all other non-hazardous materials not previously mentioned and fall under two material categories: composite and miscellaneous waste. Composite materials present challenges for recycling programs because in order to be recycled they need to be separated into their individual components (Davidson *et al.,* 2011). As such, they are typically sent to the landfill because of the incurred costs associated with the process of separating the materials into their component parts. Such materials include textiles, bulky furniture, special care waste (i.e. diapers), disposable cups, Styrofoam, tissue, latex gloves, and end of life products (Davidson *et al.,* 2011).

Non-composite soiled materials such as containers, plastic wrap, and foils normally end up as miscellaneous wastes. Their soiled nature makes them unsuitable for recycling as they would need to be cleaned and/ or dried before being accepted; these additional steps are not feasible on a large scale.

2.5 Waste Management Considerations

Depending on the type and quantity of waste material, the manner in which an organization deals with a particular stream will differ for each stage involved in the waste management process. Institutions are typically faced with a number of waste management considerations.

The first, found at most institutions, is referred to as "business as usual" (BAU). BAU refers to an institution's current waste management practices, and can be defined as the source separation of materials on-site combined with the use of external contractors to deal with materials beyond the point of source separation and collection. To go beyond this, institutions have the option of engaging in further processing of the materials, whether on- or off-site.

2.5.1 On-site Processing Practices

Instead of sending the various material streams off-site, a potential option for the university is to invest in technologies and practices that allow for material to be processed directly on-site. One potential option for institutions to manage their recyclables and fibre stream on-site is to construct a 'clean' Materials Recycling Facility (MRF). A clean MRF accepts only co-mingled, 'dry' recyclable materials (Evans 2008; Waste Technology/ MBT, 2012) but has the capability of processing paper and cardboard via installed balers within the facility.

Instead of constructing an MRF on-site, another option might be to install on-site self-contained balers to process and bale waste generated from an institution's fibre and garbage streams. An example of a local institution that has installed on its campus a self-contained garbage compactor is the Nova Scotia Community College Waterfront campus (Miller Waste representative, personal communication, June 2012). Term agreements are typically made between the institution and waste service provider regarding the installment of the technology (i.e. balers), pricing, and rental and service fees.

There are a number of potential on-site options that exist for institutions that enable the processing of organic material on-site, including vermicomposting practices and in-vessel composting technology. Windrow composting is another potential option; however, because of the space required, this alternative is better suited for off-site use. Vermicomposting is a process that involves the use of worms (usually red worms) to biologically break down and convert organic waste into a nutrient (HRM, 2012; Cochran, 2012). In-vessel composting, unlike vermicomposting, uses "forced aeration and/ or mechanical agitation to control conditions and promote rapid composting" (Aslam, n.d., para 3). The composting process takes place within an enclosed capsule and can be accomplished either by aerobic or anaerobic measures.

2.5.2 Off-site Processing Practices

A potential option for neighboring institutions and organizations is to share the expenses of constructing either a clean MRF, similar to the one located in Bayers Lake, Halifax, or a 'dirty' MRF. This research focuses on the option of an off-site dirty MRF, similar to the MRF built at the University of Illinois at Urbana- Champaign (2001), because this type of MRF would be capable of increasing landfill diversion rates. Unlike 'clean' MRFs, 'dirty' MRFs accept materials from the recyclables, fibres, and garbage streams, employing a number of sorting techniques and mechanical equipment in order to source separate mixed residual waste into recyclable and non recyclable material streams (Evans, 2008; Waste Technology/ MBT, 2012).

Because 'dirty' MRFs are not capable of processing organic materials, organics would be transported and processed elsewhere. Off-site composting practices might include the use of windrows and both aerobic and anaerobic digestion processes.

2.6 MCDA and Decision Making

Decision-making in the context of environmental problems, such as waste management, requires a decision maker to approach the issue from a multi-objective perspective that takes into consideration economic, environmental, and socio-political dimensions (Joubert *et al.,* 1997; Herath and Prato, 2006). Often these dimensions conflict with one another because of differing stakeholder interests and values (Omann, 2000; Cheng *et al.,* 2002; Herath and Prato, 2006). Herath and Prato (2006) and Begum *et al.* (2012) have suggested that decision-making support frameworks, such as MCDA, are needed to facilitate better management and policy decisions. The information basis of strategic planning, communication, and understanding in environmental management can be improved significantly using MCDA as an approach (Herath and Prato, 2006).

According to Hajkowicz, (2007), the field of environmental management has seen a significant rise in the use of MCDA methods for addressing a wide range of environmental issues over the years. It is important to state that MCDA is not intended to provide a decision maker with the "right answer" (Belton and Stewart, 2002, p.3). Instead, MCDA is designed to improve the transparency of a problem in order to facilitate the decision maker's learning, understanding, and structuring of that problem, thus leading ultimately to a desired measure of action (Prato, 1999; Fernandes *et al.,* 1999; Belton and Stewart, 2002; Hajkowicz, 2007). Additionally, MCDA is capable of integrating both qualitative and quantitative data into the decision making process, (Triantaphyllou, 2000) providing greater flexibility than a cost benefit analysis (CBA) (DCLG, 2009).

When considering different waste management alternatives, the decision-maker is required to examine a number of different alternative solutions and evaluation criteria. In assessing different waste management alternatives, a decision-maker must examine both the quantitative and qualitative components involved. As stated by Karmperis *et al.,* (2012):

> …a [waste management] project's performance is mainly influenced by financial risks, such as the energy prices and demand, as well as by environmental risks, e.g. the noises and aesthetic impact on landscape, or the impact of the project on human health, linked to pollutant emissions and contamination of the environment (p. 198).

The MCDA process is structured to allow for a collaborative planning and decision making environment that incorporates attitudes and perceptions from experts and different stakeholders into the decision-making process (Mendoza and Martins, 2006). The stakeholder approach is important because it captures knowledge and input from those with expertise and those who play an active role in the decision-making or implementation process, both internal and external to an institution. Using MCDA, the performance of a potential option can be evaluated against a set of criteria designed to integrate environmental, economic, social, and health factors. MCDA thus provides a holistic framework that can integrate the various and potentially conflicting quantitative and qualitative components of a waste management problem. It can also be used as a framework for guiding decision making, integrating the evaluation of the overall performance of multiple options using a diverse set of criteria (Sobral *et al.,* 1981; Chung and Poon, 1996; Cheng *et al.,* 2002; Generowicz *et al.,* 2011; Karmperis *et al.,* 2012; Begum *et al.,* 2012).

2.6.1 MCDA And Waste Management

A move towards using MCDA in waste management decision making has resulted in part from increased concerns for non-monetary objectives, including both environmental and social factors (Powell, 1996; Herath and Prato, 2006). In the past, decisions pertaining to institutions and waste management have typically been made with the assistance of traditional decision-making tools, such as cost benefit analysis (CBA) (Cheng *et al.,* 2002; Karmperis *et al.,* 2012). This method has become less popular amongst decision makers because of its inability to effectively account for environmental concerns and socio-political impacts (Balasubramaniam & Voulvoulis, 2005). Furthermore, attempting to monetize intrinsically non-monetary qualitative factors via CBA can become problematic, as it often results in the undervaluing of environmental and social qualities (Canter, 1994; Chung and Poon, 1996; Hipel, 1997; Cheng *et al.,* 2002). MCDA is better at handling these factors because it can take into account conflicting criteria in a multi-dimensional way (Hatami-Marbini *et al.,* 2012) and, as a result, it has recently been applied to waste management decision-making (Generowicz *et al.,* 2011; Karmperis *et al.,* 2012; Begum *et al.,* 2012; Hanan *et al.,* 2012).

2.6.2 MCDA: Weighted Sum Model (WSM)

A wide range of MCDA methods have been evaluated in the literature (Smith and Theberge, 1987; Triantaphyllou, 2000; Belton and Stewart, 2002). According to Hanan *et al.* (2012), MCDA methods that rely on intricate mathematical models and computer software might cause non-expert stakeholders to "lose confidence in the system and consequently, with the decision making process" (p. 3). The WSM is a framework that has been frequently employed by decision makers seeking a simple and transparent approach that is understandable to non-academics (Griffith and Headley, 1997; Triantaphyllou, 2000; Janssen, 2001; Herath and Prato, 2006; Hanan *et al.,* 2012). For these reasons, the WSM was applied in this study to evaluate the waste management alternatives.

There is some debate in the literature regarding the use of ordinal scales and the WSM in decision-making problems. Nonetheless, this model has been shown to be a useful framework for a decision maker faced with multiple alternatives and criteria (Griffith and Headley, 1997; Grosan and Abraham, 2007; Chowdhury and Rahman, 2008; Hanan *et al.,* 2012).

In this model, the preferred waste management alternative for a particular stream is the one with the highest weighted summation (Herath and Prato, 2006). Using the quantitative WSM model, the option with the highest final score is considered the best option (Griffith, and Headley, 1997).

2.6.3 Model Sensitivity

When using MCDA to support decision-making, the user needs to understand the sensitivity of the analytical output (i.e. in this case the decision recommendation) to the influence of various criteria. It is important to understand the specific effects of the criteria because it is sometimes possible that a small change in only one criterion weight could affect the overall preference order for a set of options (Belton and Stewart, 2002). As such, the user needs to understand the level of influence in each case and then potentially adjust the weighting to suit the objective. This is particularly true when the weighting and/ or the criterion scoring is not empirical or deterministic but rather open to subjective interpretation. When relative weights are not known or cannot be determined, alternative-weighting systems should be implemented as a means of testing the sensitivity of the solutions; that is, a 'sensitivity analysis' must be completed so that the MCDA solution can be accepted with confidence (Sobral *et al.*, 1981).

By running the WSM repeatedly with varying criterion weightings, the sensitivity analysis will indicate whether the output variability is proportional to the input variability or if the criterion in question has disproportionate influence on the final outcome. For example, if the outcome of the WSM was significantly different after altering the weights of a specific criterion, this would imply that the outcome is highly dependent on the weighting of that criterion. In this instance, the weights used were derived from a selected group of stakeholders. Thus, the sensitivity analysis was employed to investigate whether the results of the MCDA might be significantly changed if different stakeholders were involved in the weighting process.

CHAPTER 3 METHODS

3.1 OVERVIEW

To address the research questions and objectives in this thesis, a mixed methods approach was used. Methods included document review, literature review, semi-structured face-to-face interviews, focus groups, and the application of MCDA.

The document review included analyses of past waste audits that were completed at Dalhousie University, waste education materials and programs that the university currently has in place, the university's current waste management policies and procedures, past studies on waste management by previous students, and an invoice audit of the university's waste expenditures for the 2010/ 11 fiscal year. This process was necessary in order to understand Dalhousie's existing waste management system, including the material categorization of the streams, the current waste expenditures, the amounts generated, and the key stakeholders at the various management stages. A literature review was also conducted in order to better understand the waste management considerations and associated costs that could be applicable to Dalhousie given the information generated by the document review.

Interviews with key stakeholders were conducted with the aim of integrating their knowledge, experience and opinions with the information found in the literature. As well, they were expected to provide unique insights and expertise not available in the literature, specifically relating to Dalhousie and Nova Scotia. From these methods, Dalhousie's current waste framework could be identified. This allowed for a more targeted exploration of the potential waste management alternatives.

From these interviews, a refined list of evaluation criteria was presented to a focus group of key stakeholders. Participants were asked to rate or 'weight' the criteria using an ordinal scale. This was helpful in understanding how the key stakeholders viewed or rated a criterion's degree of importance in the overall assessment of a waste management system. A final list of evaluation criteria and weightings was than presented to a second focus group. Using a rating legend, participants in the second focus group rated the performance of each waste management option against the list of criteria for the fibre, recyclables, organics, and garbage waste streams. This information was used in order to determine the mode of the performance values for each option for each of the four major waste streams.

3.2 DOCUMENT REVIEW

The document review process included an analysis of past waste audits that were completed at Dalhousie University and an audit of invoice statements from contracted-out waste management service providers for the 2010/ 2011 fiscal year. As noted, the document review process was vital to understanding Dalhousie's current waste management system (e.g. materials categorization of the streams, the tonnes of waste generated per stream, identifying key actors involved at different stages of waste management at the university) and was helpful in guiding the content of the interview questions.

3.2.1 Invoice Audits

Microsoft Excel (2010) was used to organize and manage data collected from the audits of invoice statements from the external waste hauler for the fiscal period of April 2010 to March 2011. The bills for each month were first broken down into separate categories for each of the thirty-two sites on campus that the external hauler collects from. The corresponding data from the waste bills (PDFs) were manually entered into columns in under the appropriate service charge headings for each type of waste. Using the summation function in Excel (2010), columns were totaled for each of the sites on campus and a summary of the bill's totals from all thirty-two sites was calculated. The data that was transferred into Excel (2010) from the waste bill PDF's were examined to identify the average costs associated with pick up of the university's garbage, cardboard, and organics materials via the external waste service provider. The external waste service provider is not responsible for the collection of the paper materials–Dalhousie's Facilities Management is responsible for transporting paper materials to the clean MRF in Bayers Lake. Spot checks were conducted on a random basis to ensure accuracy of transferring data from the PDF's into Microsoft Excel (2010). This method of sampling and rechecking was done in order to double check the primary investigators data entry. This information was useful in assessing Dalhousie's current waste management processes, as well as the costs associated with enlisting the services of an external waste service provider.

3.3 LITERATURE REVIEW

An extensive review of literature on integrated waste management systems and waste management practices was conducted. The literature review helped to gain a broader understanding of the different components that comprise existing and current waste management practices, including institutional waste management strategies, frameworks, and planning concepts. The literature review examined waste management methodologies, including policies, practices, and plans on a global and North American scale. Peer-reviewed journals, books on the subject matter and grey literature (e.g., unpublished dissertations) were included in this review. As noted above, the review was used to inform and develop an initial set of criteria for evaluating different waste management processes for Dalhousie University. Literature regarding MCDA and evaluation criteria was also reviewed prior to conducting the interviews and focus groups. From this literature review, a preliminary list of potential waste management alternatives and criteria was created and then presented to key informants during the interview process.

3.4 INTERVIEWS

Semi-structured, face-to-face interviews were modeled on the structure of the general interview guide approach (Turner, 2010). In comparison to other interview approaches, such as the informal conversational approach, the general interview guide provides an overall structure to the interview process, while still maintaining a degree of flexibility (Gall *et al.,* 2003; Turner, 2010). This approach allows questions to be structured, providing consistency among all interviewees, but the flexibility enables the primary investigator to adapt or change questions based on participants' previous responses (McNamara, 2009; Turner, 2010). Participants for the interviews were chosen primarily based on their expertise and experience in waste management. Participants were also selected based on their position or role within Dalhousie University's waste management practices. This type of sampling can be referred to as purposive sampling (Oliver, 2006; Palys and Atchison, 2008).

From November 2011 to January 2012, requests for interviews were sent out (Appendix A). Interviews were conducted with eleven participants (ten face to face; one telephone) that represented six stakeholder groups: Dalhousie University administration and management staff involved in waste management (n=6), St. Mary's University administration and management staff (n= 1), RRFB (n=1), Scotia Recycling Limited (n=1), HRM Solid Waste Resources (n= 1), and Nova Scotia's Department of the Environment (n=1). Participants were asked 10 questions in total (Appendix B). The interviews lasted anywhere 30-60 minutes and were audio recorded, transcribed, and then analyzed using QSR's (2011) NVivo 9 software, a program used for organizing qualitative data.

The interviews were conducted in order to explore the attitudes and expert opinions of stakeholders regarding a number of waste related issues, including current and future waste management practices at Dalhousie. Another purpose of the interviews was to find out from participants what type of criteria they thought should be included in the evaluation of different waste management options.

The participants were asked specifically what type of criteria from the four categories (environmental, economical, social, and health) they would like to see used when evaluating the performance of a waste management plan. These responses were tabulated and carried over into the first focus group discussion.

3.5 Focus Groups

Two focus groups were conducted for this study. The intent of the first focus group was to support the development and weighting of the criteria to be included in the decision making process. The purpose of the second focus group was to elicit data that would help populate the MCDA model with respect to the 'scoring' of the included options against the different criteria for each of the individual material streams.

For the first focus group, thirteen invitations to participate were sent out via email (Appendix C), seven respondents, including participants from Dalhousie University's Facilities Management, attended the first focus group. To begin, a short presentation was given by the primary investigator outlining the details of the workshop and the overall study. A list of discussion questions was prepared in advance for use as a means to generate group discussion (Appendix D). The primary investigator was present to answer any questions and to provide clarification regarding the study. A preliminary list of waste management evaluation criteria was presented to the first focus group (Appendix E). The list was informed previously by literature and from the information gathered via informant interviews. Each focus group participant was given a handout with the criteria listed (Table 1) and then queried about the suitability of this preliminary list of criteria, and whether any additional criteria should be added.

Participants were then asked to anonymously rate or 'weight' the criteria using an ordinal scale of linguistic terms: 1 = Unimportant; 2 = Slightly Important; 3 = Important; 4 = Very Important; and 5 = Critical. The process of criteria weighting in terms of importance and assigning numerical values was based on a similar weighting scheme employed by Yeh *et al.* (1999) and Deng *et al.* (2011). The rating sheets were collected and statistically analyzed to determine the mode (the most frequently occurring rating) of each criterion for the main categories. This weighting exercise was helpful in determining how the participants viewed or rated a criterion's degree of importance in the overall assessment of a waste management system and the various associated processes.

Table 1. Preliminary criteria list for focus group one.

Comment Box (optional)	Rating Legend
	1 = Unimportant
	2 = Slightly Important
	3 = Important
	4 = Very Important
	5 = Critical
Criteria	Rating
Environmental Impact	
Landfill diversion rate (i.e. Recovery and reuse of materials	
Overall reduction of green house gases (GHGs)	
Enhance long term effectiveness	
Economic Impact	
Capital cost	
Operational/ ongoing costs (i.e. time, bags, bins, services, internal labour costs)	
Disposal costs/ market value for waste (i.e. Disposal tip fees)	
Payback period	
Socially Acceptable and Health Impacts	
Jobs created	
Educational benefits	
Injuries related to waste management practices (i.e. Throwing bags over shoulder)	

In the second focus group, participants were invited again from Dalhousie faculty and management, and additional invitations were sent out to members of the RRFB and Nova Scotia Environment. In total, eleven individuals were invited and ten participated. Participants in the second focus group included individuals from the initial interviewing process, as well as individuals from the first focus group. Participants from Dalhousie's facilities management (n= 10) were a source of expert knowledge regarding current waste management practices at the university, specifically the day-to-day waste management operations. The one participant from Nova Scotia Environment (n=1) worked in the waste sector for over 15 years and was able to provide a wealth of knowledge about potential future waste practices and the feasibility of different options (e.g. anaerobic digestion and vermicomposting).

An overview of the selected criteria and the waste management alternatives, developed from the document review and literature review, was provided to the participants at the beginning of the session. An explanation of the 'performance values' was then given. The performance values that were used in this evaluation process were adopted from a similar study conducted by Cheng *et al.,* 2002, wherein the numerical value was based on the option's capability of satisfying or 'meeting' the evaluation criteria for the main objective categories (Table 2). This was used to help determine the impact that each alternative would have with respect to a particular criterion (Cheng *et al.,* 2002).

Table 2. Performance values of evaluation criteria.

Evaluation criteria	**Performance value (a(ij))**
Partially meet	1
Mostly meet	2
Completely meet	3
Exceed	4
Greatly exceed	5

Participants were provided with handouts for each of the four major waste streams and were instructed to rate each option in terms what they believed to be the option's likely performance (performance value) against each of the criteria from the main objective category (Table 11; Appendix F).

Table 3. Example of blank scorecard given out to participants in the second focus group. For this example, the fibre stream was used.

Material stream (e.g. fibre)		Options		
Criteria	Weights	Business as usual/ current practices	On-site (e.g. baler)	Off-site (e.g. Shared dirty MRF)
Environmental impact				
Landfill diversion rate	Critical (5)			
Overall reduction of GHGs	Very important (4)			
Enhancing sustainability (zero waste)	Critical (5)			
Economic impact				
Capital costs	Important (3)			
Operational and disposal costs	Very important (4)			
Payback period (ROI)	Critical (5)			
Social impact				
Maximize educational benefits	Very important (4)			
Maximize employment opportunities	Important (3)			
Demonstrate community leadership	Critical (5)			
Health impact				
Minimize odours	Very important (4)			
Minimize injuries related to waste management practices	Important (3)			
Minimize noise and disturbances	Very important (4)			

The primary investigator guided the focus group through the rating process with a detailed explanation of how each option would manage the waste streams at the various operational stages (collection, transportation, processing, and disposal). In order for the participants to evaluate each option in terms of each specific criterion, the primary investigator used qualitative and quantitative data specific to each of the major waste streams in order to inform the group on an option's performance against each of the criteria. This data included factors such as annual transportation emissions from Dalhousie to the various off-site processing facilities, the difference in the payback periods or return on investment (ROI) for different alternatives, whether or not there are opportunities for new jobs based on the option, and the likelihood of injuries to employees resulting from the installation and use of different processing technologies. For a complete outline of the data given to focus group two participants, please refer to the PowerPoint handout slides that were given to the second focus group (Appendix G). Rating was done anonymously. The sheets were collected at the end of the session and the data was entered into a Microsoft Excel (2010) spreadsheet in order to determine the mode of the performance values for each option.

The focus groups provided participants with an opportunity to openly discuss their thoughts and perspectives regarding both Dalhousie's current and future waste management plan. During each of the focus groups, a flip chart was used to make notes. The notes were than transcribed into Microsoft Word (2010) and entered into QSR (2011) Nvivo 9.

3.6 NVIVO AND CODING

Nvivo 9, developed by QSR (2011), is a qualitative software program used to organize and analyze data into different themes. Qualitative software, such as Nvivo, is a helpful tool because it can provide an accurate and transparent representation of the data (Welsh, 2002). Nvivo allows the researcher to identify key themes via "coding; link similar ideas from different transcripts; identify contradictions in arguments; and compare dissimilarities in transcripts" (Gregorio, 2000, p.2). The researcher is then able to formulate arguments and analysis of the data from the synthesis of information.

A number of different forms of coding were used to analyze the transcribed interviews and focus groups. The first was *a priori* coding or deductive coding, in which the researcher uses current knowledge and existing theories to create different categories prior to analyzing the collected data (Johnson, n.d.; Stemler 2001; Beins, 2004; David and Sutton, 2004). In the second type, inductive coding, the researcher develops inductive codes after an examination of the data has taken place, with codes being created from the transcripts and texts (Johnson, n.d.; David and Sutton, 2004). In this way, themes are recognized and categorized as they emerge. Replies that contained closely related words and/ or meanings were categorized under the same theme, similar to Peckham (2010). Tree nodes (parent codes) were first created based on literature regarding waste management systems and what types of factors are helpful in assessing a plan's performance. Data from both the focus groups and interviews were coded, and themes that were similar to the initial tree nodes were categorized accordingly.

Open coding is the practice of creating new codes from emerging themes and was used during this process in order to account for themes that did not fit into the *a priori* coding framework. A number of free nodes (nodes that are not restricted to tree nodes) were also developed during this process. The coding process allowed the researcher to further analyze the data for possible relationships amongst different tree node categories. This was done using matrix coding, a form of coding that identifies how a number of different codes relate to one another (Corbin and Strauss, 2008). By using matrix coding, the primary investigator was able to identify relationships between tree nodes (i.e., criteria) and free nodes (i.e., degree of importance or intensity). Quantitative results generated by the matrix coding and overall coding process (i.e., the frequency or number of times a particular theme was mentioned) were entered into Microsoft Excel (2010), the data to be more easily compared and contrasted.

3.7 Ethical Considerations

The use of interviews and focus groups in this study required approval from the Dalhousie University Social Sciences and Humanities Ethics Board. Approval to proceed with interviews and focus groups was granted in September 2011. Research participants were requested to provide their signature on a consent form for their participation in the study, permission to be audio recorded, and use of direct quotes. Prior to the interviews and focus groups, the primary investigator went over the consent form with the participant(s) and answered any questions. The informed consent procedure made participants aware that their participation in the study was completely voluntary and that they were free to withdraw from the process at any point during the interview or focus group. All information obtained from the interviews and focus group sessions, including audio recordings and typed transcripts, were kept confidential and granted access to only the primary investigator of the study. To protect anonymity of those involved, the names of participants and associated organizations have not been included in the study; no names have been attached to quotes or ideas.

3.8 Multi-Criteria Decision Analysis (MCDA)

MCDA was employed in the study to aid in the assessment of Dalhousie's current waste management practices and potential alternative options for waste disposal and diversion. A wide range of MCDA methods exist and have been examined extensively in the literature (Smith and Theberge, 1987; Triantaphyllou, 2000; Belton and Stewart, 2002). While many differences exist among methods, the majority of MCDA methodologies follow a similar model approach (Figure 1.)

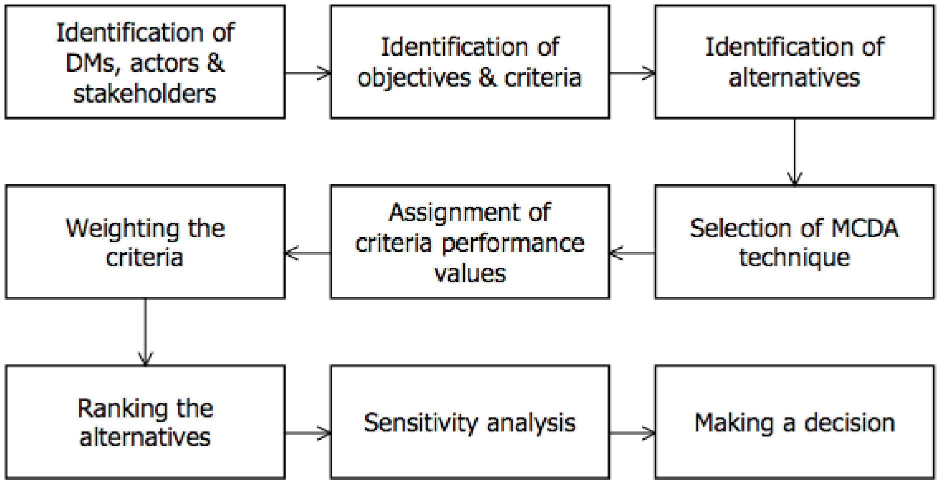

Figure 1. Summary of key steps of the MCDA process. (Adapted from Hyde, 2006, *Uncertainty analysis methods for multi-criteria decision analysis*, p. 27)

Common to many MCDA approaches is the involvement of stakeholders to assist in identifying both the alternatives to a problem and the criteria to be used for evaluating those alternatives (Belton and Stewart 2002; Cheng *et al.,* 2002; Hung *et al.,* 2007; Hanan *et al.,* 2012). They could be groups of experts, decision makers, analysts, clients, non-experts or any other stakeholder with insight or an interest in the problem's potential outcome.

Often, this group is also responsible for determining the weights of the criteria by importance and scoring or rating an option's performance against each of the selected criteria (Hanan *et al.,* 2012). The final ranking of alternatives will be impacted by the selected criteria and objectives, as the inputs to the MCDA model are determined largely by these two factors (Hyde, 2006).

In sum, all MCDA methods share three procedural steps (Triantaphyllou, 2000):

> 1. Determine the relevant criteria and alternatives;
> 2. Attach numerical measures to the relative importance of the criteria and to the impacts of the alternatives on these criteria; and,
> 3. Process the numerical values to determine a ranking of each alternative (p. 5-6).

3.8.1 MCDA: Weighted Sum Model (WSM)

According to Hanan *et al.* (2012), MCDA methods that rely on intricate mathematical models and computer software might cause non-expert stakeholders to "lose confidence in the system and consequently, with the decision making process" (p. 3). When assessing management options, the final decision is as much a political decision as a scientific one (Kontos *et al.,* 2005), and the acceptance of such decisions depends largely on public opinion (Hanan *et al.,* 2012). Thus, it is essential that the decision-making process is transparent and easily understood by laypersons. The WSM is a commonly employed method because it meets these criteria (Triantaphyllou, 2000).

Therefore, it was decided to integrate the WSM into the decision analysis process in this study. In this model, the preferred option to manage a particular stream is the one with the highest weighted summation (Herath and Prato, 2006).

In quantitative terms, the WSM can be described as:

$$P^*_{WSM} = \max_i P_i = \max_i \sum_{j=1}^{n} a_{ij} w_j \text{, for } i = 1, 2, 3..., m$$

where a weighting (w(j)) is assigned to each criterion depending on its relative importance, and the most important criterion is typically prescribed the highest weighting. A score or ranking is then assigned to each waste management alternative in terms of an alternative's performance (a(ij)) against each criterion. P^*_{WSM} is the product of criterion weightings and performance rankings of the waste management alternatives for each of the four major waste streams are calculated. As noted, the option with the highest score is considered the preferable alternative for that particular waste stream.

w(j) is the weighing assigned to each criterion depending on its relative importance. a(ij) represents the score or ranking given to each of the alternatives to denote its perceived (likely) performance as compared to other alternatives for that particular criterion (see Table 15 for example scores). P^*_{WSM} is the sum of all of the products of each criterion's weighting and performance ranking for each waste management alternative in each of the four major waste streams. It effectively denotes the 'score' of that particular alternative. The intent is to determine the option with the highest score, as it is considered the preferable alternative for that particular waste stream.

CHAPTER 4 RESULTS

4.1 Overview

This chapter will summarize the findings of the document review, literature review, and interviews with key stakeholders. First, the findings of the waste stream characterization are presented. Next, the findings of the interviews are reviewed. This includes key themes that emerged from the interviews, an outline of common/ stream-specific waste management practices at Dalhousie, and the costs associated with current and potential future practices. Lastly, the results of the MCDA are presented. This includes the list of criteria that emerged from the literature review, interviews, and focus group, the weighting of the importance of the criteria, the evaluation of the different waste management options against each criterion, and the quantitative results of the WSM.

4.2 Results of the Waste Stream Characterization at Dalhousie University

Based on the document review and insight from key stakeholders, average projections of the types and amounts of waste and materials generated at Dalhousie were developed. The following section outlines the details of that material categorization.

4.2.1. Paper/ cardboard or 'Fibre'

The fibre waste stream at Dalhousie University is composed primarily of corrugated cardboard, office paper, newspaper, boxboard, and other mixed/composite paper (Davidson *et al.,* 2011). Annual projections of the total weight generated from the paper stream collected from indoor bins, outdoor bins, and wheeled carts is between 195 and 200 tonnes per year. A recent 2011 waste audit conducted at Dalhousie University indicated that the fibre stream had a contamination rate of 13.1% (Office of Sustainability, 2011). Annual projections of total weight generated from cardboard materials are approximately 131 tonnes per year.

Currently, the university is responsible for transporting the paper stream to the Halifax MRF for processing, while an external service provider removes cardboard from the university's premises. The university also enlists four paper-shredding companies to process and recycle confidential documents.

4.2.2. Recyclables

Items that are considered to be recyclable and found on the university's campus include materials categorized as plastic containers and bags, metal, and glass. Based on previous waste characterization studies, the recyclable items found on campus include aluminum beverage cans, glass bottles and plastic beverage containers–items that accounted for 31% of the stream totals (Office of Sustainability, 2011). A recent 2011 waste audit conducted at Dalhousie University indicated that the recyclables stream had a contamination rate of 8% (Office of Sustainability, 2011). Plastics #1 (polyethylene terephthalate), #3 (polyvinyl chloride), #5 (polypropylene), #6 (polystyrene), and #7 (other plastics), as well as fibre products, were noted to be among the items found in the recyclables stream.

All recyclables from the university (minus some refundables collected for fundraising) are currently transported to Youth Live, a job experience program for individuals aged 16-30 located in the south end of Halifax, for sorting. However, it is difficult to accurately project the total annual weight generated from the recyclables stream because they are not weighed at the warehouse, nor is the material weighed at the Youth Live Environ-Depot.

Once transported from Dalhousie to Youth Live, the materials are co-mingled with streams from other organizations, businesses, or individuals that drop off material to be sorted and recycled. However, based on waste audits and trip schedules, the total annual recyclable stream was estimated to be approximately 16 tonnes per year.

4.2.3 Organics

As noted previously, organic waste is banned from landfills in Nova Scotia. As such, it is now directed to either composting or aerobic digestion facilities (van der Werf, 2010). A recent 2011 waste audit conducted at Dalhousie University indicated that the organics stream had a contamination rate of 3.7% (Office of Sustainability, 2011). Dalhousie's annual projections of total weight generated from the organics stream collected from indoor bins, outdoor bins, and wheeling carts is between 240 and 250 tonnes per year. The university currently procures the services of an external waste hauler to transport the organics collected from the campus; processing is completed offsite using aerobic digestion at New Era Technologies in Goodwood, NS.

4.2.4 Garbage

The garbage stream is often contaminated with unsorted fibre, organics, and recyclable materials. A 2010 waste audit conducted at Dalhousie University indicated that the stream was contaminated with 26% organics, 7% recyclables, and 10% paper materials (Office of Sustainability, 2011). Typically, materials found in the garbage stream at Dalhousie include items that fall under two material categories: composite and miscellaneous waste. Composite materials, such as multi-material packaging, present challenges for recycling programs because in order to be recycled they need to be separated into their individual components (Davidson *et al.,* 2011). Common composite packaging materials found in Dalhousie's garbage stream include food and condiment packaging (i.e. coffee creamers and dipping sauce containers) and chip bags. Other common materials found in Dalhousie's garbage stream include disposable cups, soiled containers, plastic wrap, and foils. Soiled containers, plastic wrap, and foils, while not composite, normally end up as miscellaneous wastes.

The annual garbage projection (collected from indoor bins, outdoor bins, loading bins, and bathrooms) is approximately 450 tonnes. Currently, Dalhousie enlists the waste removal services of an external waste hauling company. The company is responsible for removing the garbage from the 35 dumpsters that are spread across the university's campuses.

4.3 Key Informant Considerations

As noted in Chapter 2, interviews with key informants were conducted with the partial aims of 'ground truthing' the information found in the literature and providing additional insight to a particular option or management consideration's suitability. The questions related to this portion of the research were developed in order to gain insight on specific items such as perceived issues related to the current waste management practices at Dalhousie university, potential for various on-site and off-site processing opportunities, new or alternative mechanisms for increasing landfill diversion rate, perceived efficiency of different waste management practices, on-site processing challenges and concerns, utility and appropriateness of external waste service providers, and perceived market opportunities for materials. Each will be discussed in more detail below.

4.3.1 Current Waste Management Practices at Dalhousie University

Interview respondents provided detailed information of the processes involved at the collection and transportation stage for each of the four major waste streams. This included information such as the number of waste collection vehicles used on campus, the specific waste management responsibilities of the different custodial staffs, and the transfer/ movement of waste materials both within buildings and across the campus. Respondents also expressed that that actual practices sometimes differ from specified procedures depending on the campus and building type. For example, it was noted that a large building like the Tupper on Carleton Campus has its waste emptied every day due to the large amount of traffic that the building sees. This is not the case for all buildings on campus.

4.3.2 Potential On-Site and Off-Site Processing Opportunities

Attitudes towards the use of different on-site technologies to manage the campus's waste streams were generally positive. For example, all six participants interviewed from Dalhousie believed that it would be beneficial for the university to purchase baling equipment to manage the campus's paper and cardboard streams on-site. The respondent from St. Mary's University also agreed that it would be logical to install a baler on-site to manage the paper and cardboard stream. It was also suggested that some on-site technologies could be incorporated into a 'living lab' environment, whereby technologies such as balers and in vessel composters could be viewed by anyone visiting the university (e.g., members of the general public).

The recent merger with the Nova Scotia Agricultural College (Truro campus) presents new opportunities for processing waste off-site. One participant from Dalhousie suggested that, given Dalhousie's geographical situation within an urban environment, a potential option might be to transport the university's organics stream to Truro, where different organic processes could be studied (e.g. anaerobic digesters; large-scale vermicomposting; windrow composting). Participants also accepted the likelihood that new technologies would provide benefits that outweighed costs, both environmentally and economically. However, the participants from Dalhousie expressed an interested in seeing the university hire a professional waste consultant to conduct an assessment of Dalhousie's waste management practices and waste streams before committing to any one strategy, technology, or option.

4.3.3 Increasing Landfill Diversion Rate and Efficiency of Waste Management Practices

When questioned on ways that an institution like Dalhousie could increase the efficiency of its waste management practices and increase landfill diversion rates, all key informants agree that proper education on source separation of different waste material would improve the efficiency of current and future practices. It was suggested that more education, directed at both students and employees (faculty and staff), is needed. This suggestion agrees with previous studies suggesting that increased education and awareness regarding proper source separation of waste materials is critical to increasing landfill diversion rates and lowering waste management costs (UC Davis, n.d; Creighton, 1998; Fournier, 2008; Smyth *et al.,* 2010; UC Berkeley, 2011). Not having the proper education or training programs in place for employees and students was also viewed by some of the participants to be a barrier to implementing a successful waste strategy. Participants from both Dalhousie and St. Mary's noted that because the universities see a steady influx of new students every year, it is difficult keeping the university population educated. Instead of education efforts on waste management falling solely to Facilities Management or Sustainability Offices, it may be beneficial to have people in other departments and different faculties trained in best practices for waste management so that they can then provide guidance and instruct incoming employees or students. Changing the behaviours of the campus community has been cited as a major challenge to implementing a successful waste management plan. It was echoed by the participants from HRM's Waste Division that an institution must have everyone 'on board' in order to ensure a high level of compliance with proper waste management practices.

One participant suggested that in order to increase landfill diversion rates at a university, it would be beneficial to create a position with the sole responsibility of managing the specific waste streams with the view of improving diversion rates. Responsibilities could include training new staff, educating students, creating waste programs and activities– essentially promoting sustainable waste management at the university. This particular stakeholder also believed that with a switch to a more 'in house' system that employed the position of a coordinator, their institution (St. Mary's University) could see an increase in diversion of at least 25%. This participant's claim is substantiated in the literature, which shows that with the addition of a recycling/ waste co-coordinator, institutions experience an increase in landfill diversion rates and overall waste management practices generally improve (Kaplan, 2008).

Also discussed by participants was the idea of removing all single standing garbage bins from classrooms, offices, residences, hallways, and lecture halls in order to increase diversion and overall efficiency. Multi-stream stations, standardized labeling and signage, and color-coded shapes for lids (i.e. rectangular/ grey for paper, circle/ blue for recycling, oval/ green for organics, and square/ black for garbage) were concepts put forth as essential tools for increasing landfill diversion rates. The removal of standalone trash bins and the introduction of multi-stream waste source separation stations, as well as proper signage, are all activities supported in previous waste studies (UC Davis, n.d.; Stantec, 2009; Allan *et al.,* 2011; EPA, 2012).

4.3.4 On-Site Processing Challenges and Concerns

There were concerns brought up in regards to installing technologies on-site, namely issues pertaining to available space, as well as the capital and operating costs of the technology. At Dalhousie University, the warehouse is shared between facilities management and different departments (Oceanography and Geography), and space is currently limited within the warehouse. Processing technology, such as a baler or an aerobic in-vessel organic composter, would require space that may be difficult to source. It is also a challenge to store waste streams (recyclables, fibre) in the warehouse for any length of time because of the limited space.

Another concern mentioned during the interviews was health and safety. Currently, reported injuries relating to waste management consist primarily of injuries suffered by the custodial staff as a result of throwing the garbage bags over their shoulders into dumpsters (e.g., wrist and shoulder injuries). To overcome this, it was suggested that Dalhousie replace the 35 traditional dumpsters on campus with walk in dumpsters that use swinging doors.

A related issue raised by Dalhousie and Nova Scotia Environment respondents was an increased liability for the university with the introduction of on-site technologies and on-site facilities such as an MRF. This comes in the form of public nuisances relating to odor and noise. There is also a greater safety risk for university custodial and grounds staff, who would now have to be trained to operate on-site waste management machinery. Time and human resources was an additional factor raised, specifically with respect to the additional training and people required to operate any new equipment.

4.3.5 External Waste Service Providers

When asked about the changes they would like to see in contracts with outside service vendors, all stakeholders agree that greater transparency is needed. They indicated that reports should clearly outline the total weight of materials being removed from the premises and highlight all service charges per stream (e.g., whether charges are being applied per tonne of waste removed or if some other metric is being used). This is in keeping with the literature on waste management, which stresses the importance for an institution to be receiving tonnage reports from service contractors and to have this stipulated clearly in all contract language with service providers (UC Davis, n.d.).

Also noted was the lack of commitment, engagement, and accountability from particular food vendors to programs or initiatives targeted at waste reduction and source separation. However, food service companies have no incentive to change their business model because there are currently no repercussions or consequences for not adhering to waste reduction practices. This issue would need to be addressed during new contractual negotiations if the university wanted such vendors to take a more active role.

4.3.6 Market Opportunities for Materials

When addressing whether market opportunities exist for certain waste material within the ICI sector and at Dalhousie, the response from participants from the Nova Scotia Environment and RRFB noted that it depended largely on the material and the volatility of the market.

For example, paper and cardboard are both materials that are marketable resources, with institutions capable of currently receiving $50 per tonne of baled office paper and $35 per tonne of cardboard. No new or novel market opportunities were specifically identified as possible options at Dalhousie.

4.4 Waste Management Considerations at Dalhousie

The following section is an overview of waste management practices that are common to all of the major streams and waste stream-specific considerations for Dalhousie University. Each waste stream is described in terms of how it is managed at the collection, transportation, processing, and disposal stages according to existing practices, as well as potential on-site and off-site considerations.

4.4.1 Common practices

With both current and any new future practices, the custodial staff is responsible for collecting all four waste streams (organics, fibre, recyclables, and garbage) from indoor four-bin waste collection systems, while grounds staff is responsible for collecting from the three-stream (recyclables, organics, and fibre) outdoor bins as well as outdoor stand-alone garbage bins. The fibre, recyclables, and organics waste streams are all transported to a designated holding area within a building, where they are then picked up by grounds staff and transported to the warehouse for temporary storage. The collection practices for the four waste streams will remain the same for each waste management consideration, as will the transportation practices for the fibre, recyclables, and organics waste streams. These collection and transportation practices are effective and efficient.

For the off-site consideration of constructing a shared dirty MRF, the fibre, recyclables, and garbage stream would potentially be processed at an off-site dirty MRF that could be shared among neighboring institutions and organizations. Currently there is no dirty MRF–a facility capable of processing fibre and recyclables, as well as materials from the garbage stream–located in Halifax. A dirty MRF was chosen as an off-site option as it is capable of processing an additional waste stream (i.e. garbage stream) in comparison to a clean MRF. This centralized dirty MRF could be located in the south end of Halifax in existing and industrial commercial areas. These three waste streams would be collected by custodial and grounds staff, brought to a centralized location on campus (i.e., the warehouse). Dalhousie would then be responsible for transporting the streams to the off-site MRF, where the fibre, recyclables, and garbage waste streams would be processed and disposed of accordingly. Disposing of the waste at the appropriate destinations (e.g. Otter Lake Landfill, Environ-Depots, etc.) would require the services of an external waste hauler.

4.4.2 Waste Stream Specific Practices

Fibre

Waste management considerations for processing the fibre stream on-site include the installation of an on-site baler (Table 4; Table 5). Other changes that could be implemented on-site include replacing stand-alone paper and garbage bins with Dalhousie's smaller sized 'Re-think' containers, which are designed for paper and garbage collection. The cardboard stream would be processed and baled separately from the paper stream. As noted, an off-site consideration would be to have the material processed at a shared dirty MRF.

Table 4. Waste management considerations for paper stream at each operational stage.

Operational stage	Waste Management Option		
	Current/ existing practices	**Onsite processing practices (waste baler)**	**Offsite processing (Shared dirty MRF)**
Collection	-Custodial staff collect from indoor four-bin waste collection system -Grounds staff collect from buildings and three-stream outdoor bins -Confidential documents shredded on-site via four companies	-'Re-think' containers to replace standalone garbage bins in classrooms, residences, and offices	-Recycling/ waste management coordinator to coordinate collection system -Dalhousie responsible only for collection of it's waste streams
Transportation	-Dalhousie transports stream to HRM MRF (9.2 km)	-External paper waste hauler to provide transportation service of compacted bale removal 1-2 times per week (6.4 km)	-Dalhousie responsible for transporting stream to dirty MRF located in South End of Halifax (2 km)
Processing	-Custodial staff not required to inspect bags for contamination -Off campus at Halifax MRF -On-site via paper shredding companies	-Fibre baler to be installed in warehouse on main level -Paper bales produced must be stored indoor	-Stream processed off-site in shared dirty MRF via paper/ cardboard compact waste balers
Disposal	-MRF where fibre products are recycled	-Bales recycled accordingly by external waste hauler 2 to 3 times per week	-Bales recycled accordingly by external waste hauler

Table 5. Waste management considerations for cardboard stream at each operational stage.

Operational stage	Waste management consideration		
	Current/ existing practices	**Onsite processing practices (waste baler)**	**Offsite processing (Shared dirty MRF)**
Collection	- Students and staff instructed to flatten and place on floor beside paper bin - Kitchen staff from cafeterias and food outlets collect from food packaging - Custodial staff collect from source separation stations indoors	- Same as current cardboard collection practices	-Dalhousie responsible only for collection of it's cardboard stream
Transportation	- Grounds brings cardboard from buildings to dumpsters at the warehouse - External service waste provider transports from warehouse to pulp and paper mills (distance varies)	- Same as current transportation practices	-Dalhousie responsible for transporting stream to dirty MRF located in South End of Halifax (2 km)
Processing	- Front end source separation responsibility of students and faculty	-Processed via baler -Bales produced weigh approx. 360kg – 500kg and can be stored indoor or outdoor	-Stream processed off-site in shared dirty MRF via paper/ cardboard compact waste balers
Disposal	- External hauler responsible for disposing materials accordingly to various pulp and paper mills	-External hauler to dispose of bales approx. 2 to 3 times per week or as necessary	-Bales recycled accordingly by external waste hauler

Recyclables

Additional options for managing this stream include processing at an on-site clean MRF (Table 6) and, as noted earlier, off-site processing via a shared dirty MRF. As noted by interview participants, an additional management consideration might be to create the position of a recycling/ waste management coordinator. This person would be responsible for managing contracts with external service providers, creating awareness and education programs to inform the university on proper recycling behaviour, and managing the collection practices of all three campuses. Another consideration would be to increase the warehouse storage space by removing 'dead' or unused space. This would allow for more recyclable materials to be stored, thereby reducing frequency of trips made to Environ-depots.

Table 6. Waste management considerations for recyclables stream at each operational stage.

Operational stage	Waste management consideration		
	Current/ existing practices	**Onsite processing practices (Clean MRF; increase warehouse storage)**	**Offsite processing (Shared dirty MRF)**
Collection	- Residence buildings operate own collection system through elected student councils -Custodial staff collect from source separation stations indoors	- Recycling/ waste management coordinator or - Increase warehouse storage space for collection via removing 'dead space'	-Dalhousie responsible only for collection of its recyclables stream
Transportation	- Grounds staff transport materials from buildings to warehouse and-or directly to Youth Live 2-3 times per week (2 km from the university)	- Centralized clean MRF located in parking lot adjacent to warehouse on corner of Oxford and Coburg Street or - Increase warehouse storage space grounds staff would continue to transport to Youth Live for processing (2km)	-Dalhousie responsible for transporting stream to dirty MRF located in South End of Halifax (2 km)
Processing	- Front end source separation at Youth Live facility - Recyclables sorted into refundable and non-refundable containers - Non container materials such as plastic bags separated from container materials - Contaminated materials separated and processed as garbage	- Clean MRF located in parking lot adjacent to warehouse on corner of Oxford and Coburg Street) - Non container materials such as plastic bags separated from container materials	-Front end source separation of materials at shared dirty MRF
Disposal	- Non-refundable containers separated and further processed at Halifax MRF -Non container materials also processed at Halifax MRF - Contaminated materials sent to Otter Lake landfill	- Refundable containers transported by Dalhousie to local environ-depot - Non-refundable containers and non container recyclable materials separated on-site and further processed at Halifax MRF - Garbage sent to Otter Lake landfill	-Youth Live would continue to operate as environ-depot within shared MRF -Contaminated materials sent to Otter Lake landfill

Organics

One option for processing the organics stream on-site is to install an in-vessel composter (aerobic) in a centralized location on campus (Table 7). Given the recent merger with the Nova Scotia Agricultural College, a potential off-site option is to transport the organics stream to the Nova Scotia Agricultural College (now Dalhousie's Agricultural Campus (AC) in Truro) for processing into nutrient-rich compost. Off-site composting practices might include the use of windrows and both aerobic and anaerobic digestion processes.

Table 7. Waste management considerations for organics stream at each operational stage.

Operational stage	Waste management consideration		
	Current/ existing practices	**Onsite processing practices (In-vessel composting)**	**Offsite processing practices (Agricultural college)**
Collection	-External waste hauler collects bins directly from residence cafeterias and responsible for cart exchange -Yard waste collected by external hauler 'on demand' -Grounds staff collect from three-stream outdoor bins -Custodial staff collect from source separation stations indoors	- Post consumer food scraps collected in cafeterias would be macerated into 10 gallon collection containers - Grounds staff responsible for cart collection from all five cafeterias, food courts, and University club	- Same as organics on-site processing practices
Transportation	-External waste hauler transports bins directly from kitchens, and warehouse to New Era Technologies (8.0 km) - Grounds staff transport organics from buildings to warehouse	- Grounds staff transport materials from designated holding areas to a centralized in-vessel digester located on campus (0 km) - Aerobic in-vessel composter could be installed and operated in warehouse	- Grounds staff transport materials to AC located in Truro (97 km) - To avoid odours on Dalhousie campus, bins would need to be transported every 2-3 days
Processing	-Grounds staff inspect bags from indoor containers for contamination and repack into green carts to be picked up by the hauler -Organics processed off campus at New Era technologies using an 'in-vessel' system (aerobic)	- In vessel composter (aerobic) located in centralized area - Capable of processing 10,500kg of organic waste per week	- Stream processed off-site at AC - Three potential options exist due to AC's geographical location: (1) Vermicomposting; (2) Windrow; and (3) Anaerobic digester
Disposal	-Food and yard waste turned into nutrient rich compost at New Era Technologies composting facility in Goodwood, NS	-Food and yard waste turned into nutrient rich compost via in-vessel digester to be used on campus	- Food and yard waste turned into nutrient rich compost at AC - Could be sold to local farmers or used for fertilizer by campus

Garbage

A potential option for processing the garbage stream on-site is to install a compactor (Table 8) and, as noted, have off-site processing at a shared dirty MRF. Additional on-site processing considerations would be to remove all single standalone indoor and outdoor garbage gins and to replace them with four stream waste source separation stations.

Table 8. Waste management considerations for garbage stream at each operational stage.

Operational stage	Waste management consideration		
	Current/ existing practices	**Onsite processing practices (compactor)**	**Offsite processing (Shared dirty MRF)**
Collection	-Custodial staff collect from indoor waste source separation stations -Grounds staff collect from outdoor waste source separation stations	- Removal of single standalone indoor and outdoor garbage bins and replaced with four stream waste source separation stations (hallways) or 'Re-think bins' (offices) - Waste to be collected and stored in designated holding areas	-Dalhousie responsible only for collection of its recyclables stream
Transportation	- No designated holding area; custodial staff transport bags directly from buildings to dumpsters - Grounds staff transport waste from outdoor receptacles to dumpsters-External waste hauler responsible for removing materials from premises (16 km)	- Grounds staff collect and transport waste from designated holding areas to centralized self-contained compactor located on campus - Garbage to be transported to Otter Lake landfill by external waste hauler 3 times per week (16 km)	-Dalhousie responsible for transporting stream to dirty MRF located in South End of Halifax (2 km) -Materials transported to Otter Lake Landfill via external waste hauler (16 km)
Processing	- Custodial staff not required to inspect bags for contamination - Off campus at the municipal landfill (Otter Lake)	- On-site self- contained compactor (rental or purchase)	-Stream processed off-site in shared dirty MRF
Disposal	- Otter Lake Landfill	- Otter Lake Landfill	-Otter Lake Landfill

4.6 Current and Future Waste Management Costs

The costs for waste management will differ depending on the materials stream in question and the particular practice being employed. The following section provides estimates of the current and future costs associated with the various waste management considerations for the four streams. Table 9 presents the costs for the fibre stream for illustration purposes. All other calculations can be found in the Appendices (Appendices I through Q).

Fibre

Current costs

Currently the municipal MRF in Halifax does not charge Dalhousie University for fibre products coming from the paper and cardboard stream. The current costs associated with managing the paper stream include labour costs associated with a portion of time of two grounds staff members' time being used to transport the paper stream to the municipality's MRF. Incorporated into this cost is the labour required to move the material from the collection bins to the warehouse for storage. Costs also include services provided by different paper shredding companies to dispose of university office documents (Table 9).

Table 9. Current costs associated with paper stream at Dalhousie University for fiscal year April 2010 – March 2011. Cost is denoted by (-) and revenue (+).

Description	Capital cost ($)	Operating cost ($)
Operation and maintenance costs (annual)		
Grounds staff (x2) (labour) (1/3 FTE) = 2/3 FTE		-($30,000)
Vehicle (x2) (gas; upkeep)		-($1,000)
Paper shredding (four companies)		-($21,686)
Subtotal		-($52,686)
Revenue (annual)		
Subtotal		0
Total (revenue - costs)	0	+($0) –($52,686)
		-($52,686)
Final Total	**-($52,686)**	

Dalhousie University also employs an external waste hauler to collect and remove corrugated cardboard from the university's premises. According to invoices for the fiscal year of April 2010-March 2011 and data provided by key informants, the service of cardboard removal costs Dalhousie University approximately $39,000 annually. For more details on the cost calculations see Appendix H.

Future costs

On-site processing - For on-site processing considerations, an external waste service provider could supply a baler for Dalhousie University to use. The university would process and store both paper and cardboard bales inside the warehouse until collection time. A minimum 2-year agreement/ contract would be required in return for the supply and service of the baler, as well as removing the bales from the premises. The baler would require someone to 'hand feed' the paper material into it before vertically compressing the materials into a bale. Baling wire would be an ongoing operational cost that the university would be expected to purchase (Table 10). Additional labour costs of feeding the paper into the baler are negligible.

Table 10. Estimated costs associated with managing and processing paper stream on-site for Dalhousie University. Cost is denoted by (-) and revenue (+).

Description	Capital cost ($)	Operating cost ($)
Operation and maintenance Costs (annual)		
Baling wire		-($500)
Electricity		-($400)
Training	-($1000)	
Insurance		-($1000)
Subtotal	-($1000)	-($1900)
Revenue (annual)		
Selling paper bales @ $50/ tonne		+($10,000)
Subtotal	0	+($10,000)
Total (revenue - costs)		+($10,000 –($2900)
Total	**(+)$7100**	

There would be no additional cost for the university to manage its cardboard materials on-site because the baler supplied would be capable of compacting both paper materials and corrugated cardboard. Based on recent waste audit numbers and the tonnes of cardboard generated on-site, the potential revenue generated from selling cardboard bales at $35/ tonne is between approximately $4000 and $5000.

Off-site processing - The costs for an off-site 100 tonnes per day (TPD) dirty MRF include initial construction and engineering costs, equipment, and labour, as well as operating and maintenance costs associated with the processing of the fibre, recyclables, and garbage waste streams (Table 11). It is important to remember that costs would be shared equally amongst all partnering institutions. An off-site dirty MRF would most likely require financial support from the provincial government or other outside organizations. Revenue generated would depend on the intake of refundable containers and the amount of paper and cardboard processed, as well as the volatility of the market for such material.

Recyclables

Current costs

Currently, costs associated with managing the recyclables stream at the university involve the cost of employing the labour of two grounds staff to collect material on campus and transport the stream to the Youth Live facility (Appendix I). Dalhousie does not receive the revenue from the refundable containers it sends to Youth Live.

Future Costs

As noted, the university generates approximately 1151 tonnes of waste per year (50 weeks; 5 days per week), which translates to about 4.6 tonnes of waste per day for the four major streams. Peer Consultants and CalRecovery, Inc. (1991) and Recycling Marketing Cooperative for Tennessee (2003), indicate that a lower end, small scale MRF has a minimum throughput of approximately 5 TPD and a maximum of 10 TPD. Tchobanoglous and Kreith (2002) indicate that the typical costs for a low tech MRF (associated with hand sorting and processing of source separated materials only) and a high tech MRF (2d stage picking line and processing of commingled) vary from $10,000 and $40,000 tonne of capacity per day, respectively. In 1991 (the most recent published costs estimated discovered), it cost approximately $500,000 to construct a clean MRF with a throughput of 10 TPD (Peer Consultant and CalRecovery, Inc., 1991) (Appendix J). When this cost is adjusted for inflation using an inflation calculator, in 2012 it would cost approximately $1,000,000 for the construction of a clean MRF (Bank of Canada, 2012). For off-site processing costs related to managing the recyclables stream, refer to Table 11.

Table 11. Potential costs associated with managing and processing fibre (paper & cardboard), recyclables, and garbage waste streams off-site for Dalhousie University using a 100 TPD *MRF (Adopted from Peer Consultants and CalRecovery, Inc., 1991, Handbook: Material Recovery Facilities for Municipal Solid Waste and adjusted for inflation using Bank of Canada Inflation Calculator, 2012).* Cost is denoted by (-) and revenue (+).

Description	**Capital cost ($)**	**Operating cost ($)**
Facility		
Construction costs	-($1,742,647)	
Engineering costs	-($666,614)	
Equipment costs		
Misc. conveyors	-($587,244)	
Sort conveyors	-($587,244)	
Sort platforms	-($880,866)	
Trommel screens	-($51,383)	
Magnetic separators	-($110,108)	
Processing equipment costs		
Paper/ cardboard baler	-($295,046)	
Glass crushers	-($43,470)	
Metal baler	-($267,592)	
Subtotal	-($756,201)	
Additional equipment associated		
Rolling stock	-($330,324)	
Installation (10%)	-($260,177)	
Contingency (10%)	-($356,435)	
Subtotal	-($946,937)	
Operation and maintenance costs		
Labour (including sorters,		-($719,374)
Overhead		-($285,823)
Maintenance		-($82,948)
Insurance		-($133,598)
Power		-($38,170)
Water and sewage		-($1,015)
Hauling/ fleet vehicle		-($10,288)
Fuel for fleet vehicles and other		-($9,161)
Outside services and supplies (i.e.		-($98,458)
Subtotal		-($1,378,839)
Revenue (annual)		
Sales of bales		+($88,086)
Refundable containers		+($58,724)
Subtotal	0	+($146,811)
Total (revenue – costs)		+(146,811) – ($7,557,995)
Final Total	**-($7,411,184)**	

Organics

Current costs

Dalhousie University currently enlists an external waste hauling company to collect and remove organics from the university's premises. According to invoices for the fiscal year of April 2010-March 2011, the costs for managing organics were approximately $57,000 (Appendix K).

Future costs

For on-site considerations, an aerobic in-vessel composter can be purchased for approximately $79,600 (Mass Environmental Services, 2012) (Appendix L). Operational costs, including electricity costs at 36 kWh per week, for this model would be approximately $90 per month or $1080 annually (Mass Environmental Services, 2012). Dalhousie University would be responsible for providing the necessary electrical and mechanical sources required of the in-vessel composter. A single phase, 240 volt standard plug socket would be the power requirement.

A significant cost related to processing the organics material stream off-site at the AC is the transportation costs involved with transporting this stream from Halifax to Truro. At approximately $200 per round trip, 3 times per week, 50 weeks per year, transportation costs are estimated to be $30,000. Costs related to processing equipment that might be employed at AC to process the organics will differ depending on the technology used. The costs related to vermicomposting can be higher or lower in comparison to other organic processing methods (Appendix M). Other methods of processing, such as a windrow (Appendix N) and an anaerobic digester (Appendix O), range in price.

Garbage

Current costs

The current costs associated with garbage removal from the university's premises, according to an analysis of invoices for the fiscal year of April 2010-March 2011, is approximately $200,000 annually (Appendix P).

Future costs

An external waste hauler could provide an on-site self-contained compactor for processing of the garbage stream. The waste hauler would be responsible for covering any required maintenance of the equipment. There would be a cost of $149.99 (RE-Group, personal communication, June 2012) per lift plus disposal fees and a monthly rental fee of $399.99 (RE-Group, personal communication, June 2012) per month for the compacter (Appendix Q). For off-site processing costs via a shared dirty MRF, again refer to Table 11 (see above).

4.6 MCDA Results

The data from the interviews were analyzed in order to identify major categorical themes (coding category) for different criteria (codes). The broader categories, formulated *a priori* primarily from a list composed by Hirschberg *et al.* (2007), included environmental, economic, health, and social criteria. The sub-categories, however, evolved primarily from the interviews and focus groups with key stakeholders through an inductive process, although some were taken from the literature (Hanan, 2012) and were integrated *a priori*. These criteria were to be used in the evaluation of waste management options.

As noted, the first focus group was also used to rate the importance of each of the selected criteria. The number of times each criterion was mentioned in interviews, and whether or not it was discussed in the first focus group, was recorded and entered into Nvivo (Table 12). This was done in order to understand which criteria stakeholders believed to be important in the evaluation process. The number of times a criterion was mentioned by key informants was recorded and used to help determine which criteria should be included in the evaluation process. Using the brainstorming tool Bubbl.Us (2012), the broader criteria categories and sub-categories were connected accordingly based on relationship (e.g., Economic criteria-payback period; social criteria-education benefits; health criteria-injuries related to waste management practices; environment-GHG emissions, etc.) (Figure 2). The finalized criteria list (Table 13) was selected based on a combination of the data collected from the stakeholder interviews, the focus group process, and from an extensive literature review.

Table 12. Number of times in interviews criterion was mentioned and whether or not criterion was discussed in the first focus group.

Criteria for evaluating performance of waste management plan	Number of times in Interviews (/10)	Criteria discussion in Focus group (Yes/No)
Environmental impact		
Function as "Living lab"	1	Yes
Enhance long term effectiveness (zero waste)	6	Yes
Neutralize waste on site to render non hazardous	2	No
Reduction of greenhouse gases (GHGs)	8	Yes
Capture of potential natural heating sources	1	No
Focus on reduction	7	Yes
Landfill diversion rate (i.e. Recovery and reuse of materials)	9	Yes
Economic impact		
Capital cost	7	Yes
Disposal costs/ market value for waste	7	Yes
Logistical operations/ ongoing costs (i.e. Time, bags, bins, services, internal labour costs	6	Yes
Space availability	4	No
Holistic	8	Yes
Economically viable/ financial benefits (payback period) short and long term	9	Yes
User pay	1	Yes
Overall buy in from stakeholders	6	No
Social impact		
Regulations and liability of processing material on-site	7	No
Community leaders (social responsibility)	9	Yes
Synergy creation	3	No
Educational benefits	8	Yes
Employment opportunities for others in community (i.e. Disadvantaged youth)	7	Yes
Health impact		
Repetitive injuries (i.e. Throwing bags over shoulders)	6	Yes
Minimal exposure to spills	3	No
Cross contamination of health related diseases	1	No
Ease of waste removal to holding areas/ dumpsters	8	Yes
Safe handling/ transport of waste	3	No
Public health related issues from different on-site processing (i.e. Odours, rodents, pests)	10	Yes

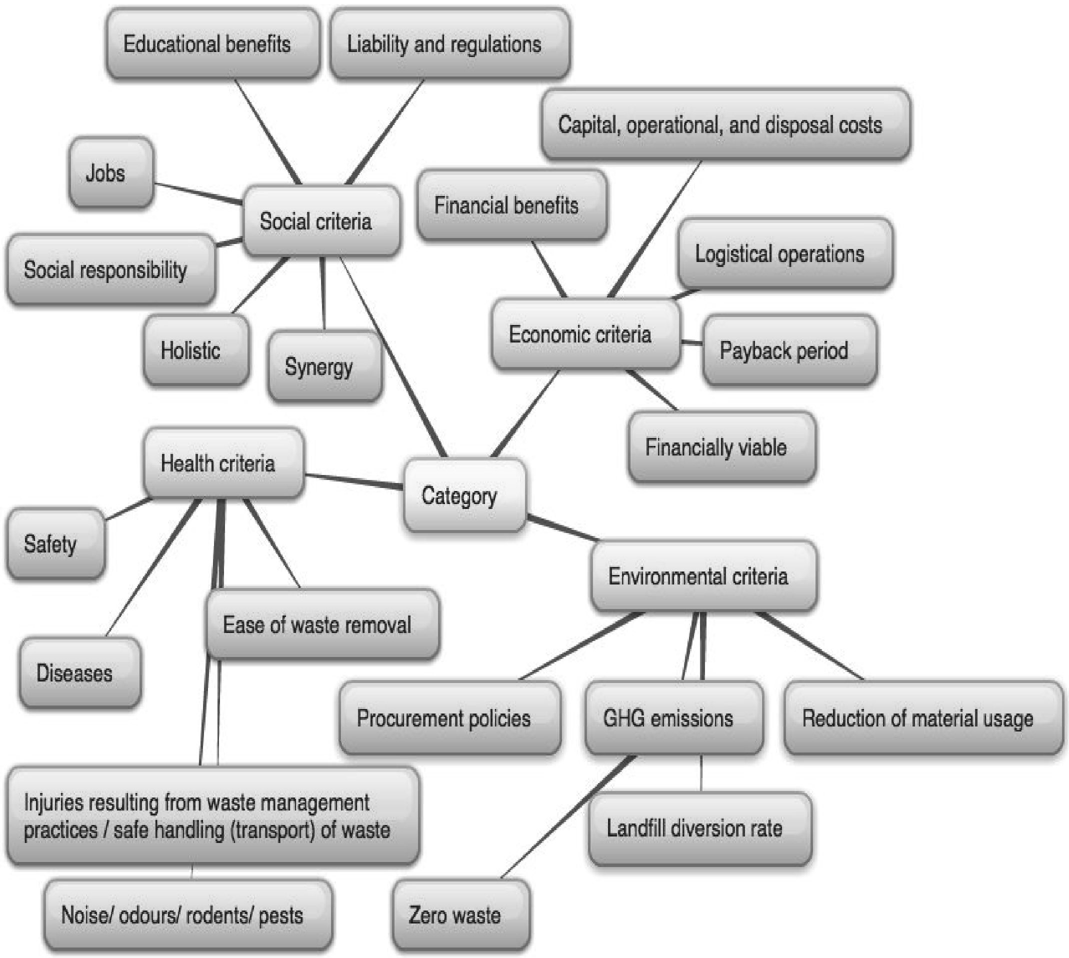

Figure 2. Resulting codes from initial coding process using the brainstorming tool Bubbl.us.

Table 13. Finalized short list of criteria and their corresponding weightings

Criteria	Description	Weighting
Environmental impact		
Landfill diversion rate	Total quantity of waste that is diverted from the municipal landfill from the university's existing waste material streams.	Critical (5)
GHGs reduction	GHG emissions from the transport of waste to the landfill site and the GHG emissions that occur in landfill waste facilities are key sustainability indicators that can be used to better understand the performance of a waste management plan (Jones, 2010)	Very important (4)
Enhancing sustainability (zero waste)	Principles of re-think (purchasing to reduce waste), reuse, recycle, and recover. A zero waste framework has the potential to reduce waste management costs, reduce purchasing of goods (Jones, 2010).	Critical (5)
Economic impact		
Capital cost	Initial start-up costs incurred when purchasing equipment to be used in managing an institution's waste streams.	Important (3)
Operational & disposal costs	Costs related to operating equipment, the collection and storage of material, signage, and as well as human resources. Disposal costs include tipping fees and the service required to remove the materials from an institutions premises (UC Davis, n.d.).	Very important (4)
Payback period (ROI)	Length of time required for an investment's net cash receipts to cover the initial capital investment (Scott, 2003).	Critical (5)
Social impact		
Maximize educational benefits	Education on proper waste sorting practices can help shift human behaviour and increase public support for waste management (Davidson, 2011)	Very important (4)
Maximize employment opportunities	By creating employment opportunities, the university can contribute positively to the local economy by employing local labour.	Important (3)
Demonstrate community leadership	Incorporating public participation and making sure that individuals understand their roles within a waste management system, social acceptability of a waste management plan is more likely to be reached (Macdougall et *al.,* 2001)	Critical (5)
Health impact		
Minimize odours	Odours stemming from processes such as onsite composting can be a nuisance to the public and also a health hazard.	Very important (4)
Minimize injuries related to waste management practices	A waste management plan must be in full compliance with health and safety regulations and should include a health and safety component (CCME, 1996)	Important (3)
Minimize noise & disturbances	Waste management practices must be in accordance with regulations set out in municipal by-laws.	Very important (4)

The criteria weightings in terms of importance for each of the indicators were finalized from the first focus group after the participants rated/ weighted the importance of each criterion (See also Table 13). The results from the weighting exercise conducted in the first focus group indicate that none of the selected criteria used in evaluating waste management options should be considered unimportant. It was observed that landfill diversion rate, enhancement of sustainability/moving towards a zero waste framework, payback period, and demonstration of community leadership are all ‘critical’ factors to consider when evaluating the performance of a waste management option and received the highest possible importance rating.

When using a WSM, the approach is to normalize the weights of the criteria so that each main category (e.g. environmental) adds up to one. While controversial in some fields (Barzilai, 2010), mathematical manipulations of ordinal scales have been done in previous studies (Abrishamachi *et al.,* 2005; Chowdhury and Rahman, 2008; Ahn and Choi, 2012). To normalize the criteria weightings, a method similar to that used by Abrishamachi *et al.* (2005) was adopted. Computing the normalized weight (w(j)) of each criterion was done by dividing the assigned weight from the first focus group by the sum of the criteria weights within each objective. For example, landfill diversion rate was given an overall weighting of 5 (representing ‘Critical importance’). That weighting was then divided by the sum of the criteria weights within the ‘Environmental impact’ category (14) for a final weighting score of 0.3571. This was done for each criterion weighting that was assigned from the first focus group (Table 14).

Table 14.List of criteria, focus group weightings, and normalized weightings.

Criteria	Focus group weighting	Normalized weighting importance values (w(j))
Environmental impact		
Landfill diversion rate	Critical (5)	0.36
GHGs reduction	Very important (4)	0.29
Enhancing sustainability (zero waste)	Critical (5)	0.36
Economic impact		
Capital cost	Important (3)	0.25
Operational & disposal costs	Very important (4)	0.33
Payback period	Critical (5)	0.42
Social impact		
Maximize educational benefits	Very important (4)	0.33
Maximize employment opportunities	Important (3)	0.25
Demonstrate community leadership	Critical (5)	0.42
Health impact		
Minimize odours	Very important (4)	0.36
Minimize injuries related to waste management practices	Important (3)	0.27
Minimize noise & disturbances	Very important (4)	0.36

As noted, the intention of the second focus group was to have key stakeholders rate the performance of the waste management options against each criterion from the finalized list. Similar to the weighting of the criteria, linguistic terms (e.g. 'Important' and 'Very Important') were also used as performance value measures (Please refer back to Table 10). Participants rated each of the three options in terms of the option's ability to satisfy the evaluation criteria, and the 'mode' of the each series of ratings was determined for each of the four streams (Table 15).

Table 15. Performance value ratings from focus group two for each criterion for different options.

Criteria	Waste management option: Business as usual (BAU)/ current practices				On-site processing				Off-site processing			
	Fibre	Recycling	Organics	Garbage	Fibre (compact waste baler)	Recycling (Clean MRF)	Organics (In-vessel digester)	Garbage – (compactor)	Fibre (Shared dirty MRF)	Recycling (Shared dirty MRF)	Organics (Agricultural campus)	Garbage (Shared dirty MRF)
Environmental impact												
Landfill diversion rate	3	4	3	3	5	5	5	4	5	5	5	5
GHGs reduction	3	4	3	3	4	4	5	4	4	4	2	4
Enhancing sustainability (zero waste)	3	3	3	3	4	4	4	4	4	4	3	4
Economic impact												
Capital cost	3	4	4	4	4	1	3	3	2	2	4	2
Operational & disposal costs	2	4	2	2	4	1	5	4	2	2	2	2
Payback period	3	4	3	3	4	1	4	4	2	2	3	2
Social impact												
Maximize educational benefits	3	3	3	3	4	5	4	4	5	5	4	5
Maximize employment opportunities	3	4	3	3	4	4	3	3	4	4	4	4
Demonstrate community leadership	3	4	3	3	3	3	5	4	4	4	4	4
Health impact												
Minimize odours	4	4	5	3	5	3	4	4	3	3	4	3
Minimize injuries	3	4	3	2	3	3	4	4	2	2	3	2
Minimize noise & disturbances	3	4	2	2	4	3	4	4	3	3	2	3

4.6.1 Quantitative Results: Weighted Sum Model (WSM)

Using the normalized weights (w(j)), the performance values (a(ij)) (Table 14) and the results from the second focus group (Table 15), the weighted sum results were tabulated for the four streams. Table 16 presents the tabulation for the fibre stream for illustrative purposes; all other calculations can be found in Appendices R through T.

Table 16. Weighted score tabulation for fibre stream.

Criteria	**Weighting (w(j))**	**Waste management option**		
		1.Business as usual	**2.On-site processing**	**3. Off-site processing**
Environmental impact		**BAU/ current** (w_{jBAU} a_{ij})	**Compact waste baler** (w_{jCWB} a_{ij})	**Shared dirty MRF** (w_{jSDM} a_{ij})
Landfill diversion rate	0.36	0.36 x 3 = 1.08	0.36 x 5 = 1.8	0.36 x 5 = 1.8
GHGs reduction	0.29	0.29 x 3 = 0.87	0.29 x 4 = 1.16	0.29 x 4 = 1.16
Enhancing sustainability (zero waste)	0.36	0.36 x 3 = 1.08	0.36 x 4 = 1.16	0.36 x 4 = 1.16
Economic impact				
Capital cost	0.25	0.25 x 3 =0.75	0.25 x 4 = 1	0.25 x 2 = .50
Operational & disposal costs	0.33	0.33 x 2 = 0.66	0.33 x 4 = 1.32	0.33 x 2 = 0.66
Payback period	0.42	0.42 x 3 = 1.26	0.42 x 4 = 1.68	0.42 x 2 = 0.84
Social impact				
Maximize educational benefits	0.33	0.33 x 3 = 0.99	0.33 x 4 = 1.32	0.33 x 5 = 1.65
Maximize employment opportunities	0.25	0.25 x 3 = 0.75	0.25 x 4 = 1	0.25 x 4 = 1
Demonstrate community leadership	0.42	0.42 x 3 = 1.26	0.42 x 3 = 1.26	0.42 x 4 = 1.68
Health impact				
Minimize odours	0.36	0.36 x 4 = 1.44	0.36 x 5 = 1.8	0.36 x 3 = 1.08
Minimize injuries related to waste management practices	0.27	0.27 x 3 = .81	0.27 x 3 = .81	0.27 x 2 = 0.54
Minimize noise & disturbances	0.36	0.36 x 3 = 1.08	0.36 x 4 = 1.44	0.36 x 3 = 1.08
Total Score		**12.03**	**15.75**	**13.15**

The total scores of each of the three management options for each waste stream indicated that on-site processing practices are the most preferable options for managing the fibre, organics, and garbage streams, while the current practices are preferable for management of the recyclables stream (Table 17).

Table 17. Overall weighted sum tabulation for waste streams and waste management options. The preferable option for each stream is highlighted in grey.

Waste stream	**Waste management option**		
	1.Business as usual	**2.On-site processing**	**3. Off-site processing**
Fibre	12.03	15.75	13.15
Recyclables	15.31	12.38	13.43
Organics	12.28	16.29	12.99
Garbage	11.29	15.75	14.57

<u>Sensitivity analysis (Results using equal criterion weightings)</u>

Maintaining all other original values, the WSM equation (EQ 1), was used to re-calculate the weighted sum for each waste stream using a criterion weighting of 0.33 for all criteria. The results are presented in Table 18 and show a similar decision output as with the original weighting.

The total scores for each waste stream indicate that on-site processing is the most preferable option for managing the fibre, organics, and garbage streams, while current practices are the best choice for managing the recyclables stream.

Table 18. Overall weighted sum tabulation for waste streams and waste management options using equal criterion weighting. Preferable option for each stream is highlighted in grey.

Waste stream	**Waste management option**		
	1.Business as usual	**2.On-site processing**	**3. Off-site processing**
Fibre	10.65	15.84	13.2
Recyclables	15.18	12.21	13.20
Organics	12.21	16.17	13.20
Garbage	11.22	13.19	12.87

Option 2 was rated considerably less favourable in terms of the capital, operational and disposal costs criteria associated with the construction of an on-site clean MRF. Only Option 3 (dirty MRF) is capable of increasing landfill diversion rates, but this comes at a price. Capital costs for an MRF, as it currently stands, are difficult to justify by stakeholders with payback periods well above 10 years.

Chapter 5 DISCUSSION

5.1 Overview

The data collected as part of this investigation enabled the development of an appropriate decision-making structure that would support the effective management of Dalhousie's various waste streams. A number of considerations emerged from this research that may have broader applications, particularly with respect to measures that may be adopted in other institutional settings.

5.2 Importance of Education

While not a component of the MCDA framework used in this study, both interview and focus group participants and the literature (Creighton 1998; Armijo de Vega *et al.,* 2008, Esseltine *et al.,* 2010; Smyth *et al.,* 2010) indicated that education is fundamental in achieving and maintaining higher diversion rates. Education on how to properly source separate waste material is critical to preventing the contamination of waste streams. Less contamination will improve the overall efficiency of waste management practices (e.g., for processing on-site via balers and in-vessel composters) as employees will not have to spend valuable time on source separating materials. Coupling policy with educational measures is an excellent way of encouraging stakeholders to participate in sustainable waste practices and has the potential to maximize the success of any formal waste strategy (Harris and Probert, 2009; Smyth *et al.,* 2010).

5.3 Importance of Document Review and Auditing Service Invoices

A document review of past waste audits is important, as it reveals the actual current state of the institution's waste management. It provides an understanding of the material characterization of an institution's waste stream, including material type and generated quantities. For example, it was learned from the review of past waste audits that the garbage stream is the most contaminated stream on campus (53.20%), suggesting that more education is needed regarding proper source separation of waste materials. As another example, knowing that the total tonnage of fibre generated on campus per year is approximately 380 tonnes indicates that a baler would be a suitable option for the university. This knowledge is therefore critical when considering future waste management alternatives.

Auditing service invoices is important in order to understand how much of an institution's operating budget is spent on waste removal services and to identify inefficiencies in that spending. Many institutions typically require a waste removal service at some point during operations and this service is often provided by a third party or external waste service provider, leading to significant expense (Creighton, 1998; Davidson 2011). Knowing how much an institution spends on waste management services is not only essential for understanding current practices, but is also useful in guiding the development of waste management alternatives. As indicated by Creighton (1998), data on an institution's generation of solid waste can "have direct environmental and financial consequences" (p. 33) on future waste management practices. Moreover, understanding operational costs related to waste management is important in order to educate institutions on potential cost savings and identifying alternatives that are more cost-effective (Creighton, 1998).

The invoice audit provided information about the existing costs related to management of the various waste streams that are dealt with by external service providers. For example, during the fiscal year beginning April 2010 and ending March 2011, Dalhousie University spent approximately $220,000 on waste removal services from the external waste service provider (Appendix H). The invoice audit also showed that the university is charged for waste removal by weight (per tonne) despite the fact that there was no specific indication in the invoices of the tonnage of material being removed from Dalhousie's premises. While the Waste Collection Services-Agreement requires service providers to report the tonnage of materials removed from the university's premises, the weights were not reported or included on the monthly statements issued to Dalhousie

University. Analyses also revealed inconsistencies among pick-up fees and fees associated with the organic cart exchange program where lift fees appear to fluctuate. For example, a solid waste lift fee one month might be $7.09 and then next month rises to $8.75; no explanation for these changes is provided.

After conducting an audit of Dalhousie's waste service invoices, it was apparent that the primary service provider is not in compliance with certain aspects of the signed terms of agreement. It is stated in most waste collection agreements that the service provider is required to provide the institution with weight tickets on a monthly basis that indicate the amount and type of waste material being removed at a specific location (UC Davis, n.d.). As was previously noted, weight tickets were not provided. This is problematic for a number of reasons. Without weight tickets, it is difficult to establish an accurate baseline of waste materials flow, and without this information it is difficult to evaluate the successes and failures of a waste strategy and the potential implications of the various management practices.

In the absence of weights, the institution cannot use the tonnage of waste being removed from the property to determine the amount they "should" be paying for the service. According to UC Davis (n.d.), institutions can have it stated in their collection agreements and contracts that dedicated vehicles are required for waste removal, meaning that the collection truck would arrive to the premises either empty or with a calculated net weight. The purpose of this is to ensure that an accurate weigh bill can be calculated. Service categories listed on the invoice should also be explained clearly so that an institution knows exactly what services they are being charged for. Invoice statements from waste collection companies need to be transparent, with no ambiguity. Waste collection agreements with third party service providers are an important component of the successful implementation, monitoring and evaluation of a formal waste strategy (CCME, 1996; Davidson, 2011).

Frequency of collection should be stipulated in the waste services contract and negotiated between the university and service provider (Scarlett and Sloan, 1998). Monthly auditing of the dumpsters around campus can provide valuable information regarding the type/ characterization of materials from the garbage stream entering the dumpster, which in turn can indicate the necessity of particular dumpsters on campus (Davidson and Owen, 2011). Reassessing the number of dumpsters on campus required in order to effectively manage the garbage generated from both interior and exterior bins has the potential to reduce service costs through simple elimination of unnecessary dumpsters.

The consequences of a failure to perform waste collection and removal services can be stipulated in the contract. Missed pick-ups, trouble accessing bins, and inadequate maintenance of dumpsters could be considered ‘non-performance’ (Wipe Out Construction, n.d.; CCME, 1996; Davidson, 2011). Any issues that prevent the company from conforming to the contracts (e.g., a dumpster being blocked such that the waste removal company can’t access it) need to be reported to the institution so that such problems can be resolved in a timely manner. It’s important to note that the contracted company could face minor sanctions such as initial verbal warnings, but could also be dealt a financial penalty or termination of the contract for failing to perform the basic services as stated in the contract (UC Davis, n.d.).

5.4 Importance of Stakeholder Engagement in Understanding Current Waste Management Practices and Potential Future Alternatives

Engaging key stakeholders is crucial to understanding an institution’s current waste management practices. However, their feedback is just as crucial or possibly even more so with respect to determining the feasibility of potential future alternatives/ considerations, as interviewees can draw on their unique expertise and experiences to either support information from the literature or to provide new information that casts an option in new light. The balance of this section speaks to the specific comments that stakeholders made with regards to the various technology options.

Interview findings revealed that stakeholders generally believed that the use of on-site technologies (e.g., a baler for the fibre stream, an aerobic in-vessel organic composter for the organics stream, and a compactor for the garbage stream) would result in a more efficient management of the waste material streams. Such technologies reduce the collection frequency (by external service providers) and also reduce lift fees; however, they do not increase landfill diversion rates. Technologies such as balers, compactors, and in-vessel composters will have no impact on landfill diversion rates if materials are not properly source separated upfront by the waste generators (e.g., staff and students). Other measures to improve diversion include education, bin placements and reduction (i.e. removing single use bins), and signage. Stakeholders also noted that the fibre and organics streams are front end sorted in the campus warehouse by grounds staff, suggesting that it could be feasible to install on-site a compact waste baler to process the fibre stream and an aerobic in-vessel composter to process organics. A compactor for managing the garbage stream was also deemed potentially feasible. These on-site technologies were therefore integrated into the MCDA framework as potential options for the university to adopt.

However, while logistically possible, many participants did suggest that some organics-processing technologies, such as an anaerobic digester or a large-scale vermicomposting facility, would be difficult install on-site due to potential permitting issues at the Halifax campuses. Odors and the potential for public nuisance are among the issues that may interfere with obtaining the necessary zoning permits. However, both technologies were considered potentially feasible by stakeholders, if installed on the Agricultural Campus, and were integrated into the MCDA framework as potential options.

Participants agreed that having a clean MRF located on campus would be a novel way to manage the recyclables and fibre streams. However, landfill diversion rates would not increase because the same materials would be processed whether on-site or at the HRM MRF. Health and safety concerns were expressed by some participants regarding hand injuries (e.g., musculoskeletal injury) that might result from repetitive wrist motion related to the front end sorting of materials. Conversations with local Halifax MRF and

Otter Lake Landfill facility representatives indicate that this type of injury rarely occurs due to extensive training and safety procedures. Most MRFs, including the Halifax MRF, employ the use of manual labour to front end sort the materials. With an off-site shared dirty MRF, participants agreed that higher diversion rates would result. Preliminary concerns were expressed over the initial capital costs to construct such facilities and where the funding would come from. Both the on-site option of constructing a clean MRF and the off-site option of a shared dirty MRF were deemed by stakeholders as potential options for Dalhousie University to manage its waste streams and were incorporated into the MCDA framework.

5.5 Importance of Stakeholder Approach in the Application of a MCDA Framework for Dalhousie University

The stakeholder approach was used in the application of an MCDA framework that would allow Dalhousie University personnel to determine and evaluate which alternatives are most appropriate within the Dalhousie, HRM, and Nova Scotia contexts. Having different inputs from people who are actively involved in waste management activities at the university is important for the success and believability of the outcome. If people do not believe the information going into the decision-making process, they are most likely not going to believe or trust the information that comes out of that process (Schwilch *et al.,* 2012). The stakeholder approach was used to capture knowledge and input from those with expertise who play an active role in waste management, both internally (e.g., custodians) and externally (e.g., Nova Scotia Environment).

The interviews and the first focus group session were important in understanding the type of criteria that different stakeholders consider to be important and should be taken into consideration when assessing waste management alternatives. The final short list of criteria (n = 12) was based largely on the number of times interviewees and focus group participants mentioned particular criteria, as well as Hirschberg *et al.*'s (2007) list of criteria factors.

Moreover, many of the criteria identified by the research participants were similar to the criteria identified within the literature, including such factors as reduction in GHG emissions, health risks, odor and noise, capital costs, operational and disposal costs, marketability of materials, and overall social acceptability (Chung and Poon, 1996; Chowdhury and Rahman, 2008; Guglyuvatyy, 2010; Hanan *et al.,* 2012)

Incorporating the opinions and views from different stakeholders is an important step in the overall development of a waste management plan for institutions (Tchobanoglous and Kreith, 2002), as supported by various studies. In Chung and Poon (1996) and Chowdhury and Rahman (2008), the researchers sent out questionnaires to individuals representing viewpoints from environmentalists, governmental and decision makers, academics, the private sector, and technical groups asking them to rank the relative importance of each criterion. Similarly, in Hanan *et al.* (2012), stakeholders were asked to rank the criteria on a scale of 100 based on their view of the relative importance of each criterion.

In terms of rating the options, the second focus group, similar to Hanan *et al.,* (2012), was guided through the rating process based on information provided to them by the primary investigator. In order for the participants to evaluate or 'score' each option in terms of specific criteria, qualitative and quantitative data specific to each of the major waste streams was used to help inform the group on how each option would perform against different criterion. One criticism of this approach could be that the data and information provided to the focus group was not given to the members prior to the session (Hanan *et al.,* 2012), thereby preventing the members from reviewing the facts and verifying the accuracy of certain statements. However, during the rating exercise, one participant from Nova Scotia Environment was able to provide his professional opinion regarding some of the statements made regarding items such as the costs of constructing an on-site MRF and certain on-site technologies, such as anaerobic digestion and vermicomposting.

Another participant of the focus group was responsible for grounds management at Dalhousie. As such, he/ she had extensive experience and knowledge regarding Dalhousie's current waste management practices and was able to answer questions or clarify statements that had to do with current waste practices at the university.

During both focus groups, discussion was generated regarding particular waste management options and the impact they would have on university operations. For the discussion aspect of the focus groups, it was impossible to uphold anonymity due to the strong likelihood that some participants knew each other. In a large group setting participants may be more reserved with their comments depending on how comfortable they feel about discussing their opinions in a group environment (Walden, 2008). To compensate for this possibility, focus group participants were encouraged to write down any comments that they had in the comment section that was provided during both sessions. Moreover, most focus group participants were familiar with one another prior to the sessions, resulting in a relaxed environment where people were not hesitant to share their views towards particular ideas. However, an important point to make is that the focus group responsible for rating the performance of each option was not the same focus group that initially weighted the criteria. From the ten participants involved with the rating of the options, only three from that group were also involved with the weighting of each criterion. That being said, all participants involved in the rating of the options also were involved with the overall criteria selection process during the interview stage.

The preferable scenario to waste management at the university would be a combination of different components from all three options. Given the high capital costs associated with Option 2 and Option 3 (construction of a clean and dirty MRF, respectively) to manage the recyclables stream, an observer might rate Option 1 (BAU/ current practices) as being the optimum alternative for this particular waste stream. The WSM substantiates this claim with the weighted tabulations of each option for the recyclables waste stream (Table 17; Table 18). Ideally, the ultimate alternative for waste management at Dalhousie would be a combination of a number of different practices from each of the options. The university currently transports its recyclables stream to Youth Live, a job experience program for individuals aged 16- 30, that front end source separates the material. The university supports youth employment and provides an additional income stream to the organization by allowing Youth Live to retain all profits made from the refundable containers it receives from Dalhousie. Instead of constructing an on-site clean MRF to manage the recyclables stream, the university could continue to maintain this relationship with Youth Live but look to equipment such as balers for processing the paper and cardboard stream on-site, as well as compactors to manage the garbage stream and an aerobic in-vessel digester to manage its organics stream.

These on-site technologies are capable of reducing costs associated with factors such as the frequency of pick-ups. The payback period for compact waste balers for the fibre is relatively short, with the university being able to sell the material back to the market for revenue gains. Therefore, the optimum alternative should involve a combination of all three options to manage the four major streams as opposed to just one particular option.

5.6 MCDA/ WSM as a Means to Evaluate Waste Management Options

Unlike other MCDA models that involve complex matrices and mathematical equations, such as Fuzzy MCDA and ELECTRE (See Triantaphyllou, 2000; Belton and Stewart, 2002), using the WSM to perform the mathematical computations within the MCDA allows details of the evaluation to be easily communicated to and understood by both specialists and the general public alike. Because of this transparency, the WSM was an appropriate model to employ in this study and can be used in future waste studies that involve both the general public and specialists. Qualitative terms were used for both the weighting of the criteria in the first focus group and the performance values used to rate the options in the second focus group session. Using qualitative parameters such as ‘Very important’ or ‘Completely meet criteria’ are also intuitively simple measures for stakeholders attending a focus group to understand (Yeh *et al.,* 1999).

An MCDA that integrates the WSM is a framework that allows the integration of perspectives from different stakeholders, thus providing a holistic approach to decision making. In Chowdhury and Rahman (2008) applied a WSM-based MCDA framework to water resource management in order to determine the best alternative for improving water channels in Sylhet, Bangladesh. The authors interviewed different stakeholders, including the local community and experts in the field, for the selection of criteria and to ascertain the weighted factor scores for each criterion (Chowdhury and Rahman, 2008).

From this, nine criteria from four categories (technical, economic, environment, and social) were selected, and the relative performances of alternatives were than evaluated using the WSM. Using this approach, the authors found that the best alternative for improving the water channels was through natural sodding (Chowdhury and Rahman, 2008).

The use of WSM-based MCDA as a framework for assisting decision makers is also supported in the waste management literature. In Hanan *et al.* (2012), the authors used a similar analysis to evaluate seven different options for managing waste paper on the Isle of Wight. The authors used a set of criteria that could be easily understood by non-experts, as well as experts. Moreover, the use of simple arithmetic to assess the options was understood by all stakeholder participants, resulting in a completely transparent process (Hanan *et al.,* 2012). The study demonstrated that WSM-based MCDA can be applied to waste management decision-making because the process successfully incorporates the perspectives of the general public and opinions of experts (Hanan *et al.,* 2012). In accordance with conclusions from Chowdhury and Rahman (2008) and Hanan *et al.* (2012), the results of this research indicate that MCDA and the simplicity of the weighted sum approach can be an effective framework for statistically analyzing the qualitative attitudes and engaging different stakeholders, both experts and non-experts, in the waste management decision making process.

5.6.1 Sensitivity analysis

Similar to Hanan *et al.* (2012), a sensitivity analysis was conducted in this study in order to determine whether or not altering the weight of a specific criterion would impact the final outcome. After adjusting the weighting importance for each criterion to equal weightings, the outcome did not change. This indicates that the WSM results were not affected by a change in equal criterion weightings. In other words, the sensitivity indicates that the preferences would not have been altered had another group of stakeholders been a part of the original criteria, weighting 'selection' and scoring process.

The sensitivity analysis supported the focus group's preference for on-site processing practices for the fibre, organics, and garbage streams, while maintaining the current recycling practices for the recyclables stream. This suggests that the preferences would not have been altered had another group of stakeholders been a part of the original criteria and weighting 'selection' and scoring process.

5.7 Research implications and contribution to scholarship

This study offers an approach that other institutions can employ for assessing their current waste practices and for developing potential waste management options. It provides an example of how MCDA can be used for waste management decision making at the institutional level.

A number of studies have been carried out that explore the use of MCDA and waste management decision making at the municipal level (Sharifi *et al.*. 2009; Karagiannidis and Perkoulidis, 2009; Garfi *et al.,* 2009; Geneletti, 2010; Hanan *et al.*. 2011; Hanan *et al.,* 2012; Yesilnacar *et al.,* 2012) but at the institutional level it is not well documented (Zhang *et al.,* 2011; Dursun *et al.,* 2011**).** From this study, other intuitions may adopt a similar approach to conducting waste management decision-making, utilizing MCDA and WSM as means to integrate stakeholders into the evaluation process.

Insight as to who these key stakeholders/ informants should be is provided in this research. The research also provides institutions with a set of criteria that may be used for evaluating their own options for managing waste streams.

CHAPTER 6 CONCLUSION

6.1 Revisiting the research purpose

As noted in this study, Dalhousie University currently does not have a comprehensive waste management plan based on detailed option analysis. It was the intent of this research to address this shortcoming and to provide a framework that would facilitate the selection of waste management options that are stakeholder inclusive. The first objective of this study was to examine Dalhousie University's current waste management practices and the characterization of the fibre, recyclables, organics, and garbage streams. The second objective was to apply an MCDA framework that would aid Dalhousie managers in determining and evaluating alternatives within the Dalhousie, HRM, and Nova Scotia contexts. Based on the results of this study, recommendations were made that will help guide Dalhousie and other institutions in identifying and selecting waste management options that is stakeholder inclusive.

6.2 Conclusions and recommendations

The results from this research provide an important first look into the waste disposal and diversion options that could be incorporated into Dalhousie University's waste management procedures. In this research, Dalhousie University was used as a case study to determine how MCDA could be applied to waste management decision making within an institutional context. As previously noted, waste management decision making within an institutional setting requires the cooperation of different stakeholders.

Dalhousie's current waste framework was assessed using several approaches: interviews with stakeholders, examination of existing waste policies, procedures, and policies; and audits of invoice statements from waste collection agencies. From this initial understanding, potentially suitable options for waste management at the university could then be developed and assessed.

When considering different waste management alternatives, it is important for institutions to know the quantity of waste being generated by each of the major streams, as well as each stream's characteristics (Smyth *et al.,* 2010). As shown in this study, a document review of past waste audits and relevant waste studies conducted at the institution can be helpful in determining the quantity and characteristics of waste being generated on-site. Consultations with individuals that play active roles in day-to-day waste operations are crucial in better understanding an institution's current waste management system and the feasibility of potential options for waste management, as was the case in this study. Furthermore, stakeholder consultation can also reveal areas for improvement and identify inefficiencies in the management process. Understanding how waste streams are currently managed provides the foundation upon which potential future options can be evaluated using relevant literature and information from expert informants.

In Summary, a WSM-based MCDA was used in this study as a means to evaluate three typical options for waste management at the institutional level: 'Business as usual' (BAU)/ current practices, on-site processing of waste materials, and off-site processing of waste materials. As noted in this study, there is not necessarily one single option that is best for all the streams. Some streams may best be managed using off-site practices, while current practices or on-site processing may be the best option for other streams. Options for waste management may differ depending on the materials stream and its characteristics.

In order to apply the MCDA model, a number of steps should be carried out. A document review should first be conducted in order to better characterize an institution's waste streams, including the tonnes of waste generated per year by each stream. This information can then be used to guide the literature review in identifying potential options that suit the institution. Knowledge and expertise from interviews and focus groups with key stakeholders can then be used to inform the development of evaluation criteria, rate the importance of each criterion, and rate the overall performance of a given option against specific criterion. The results of this research indicate that MCDA and the simplicity of the WSM approach can be collectively serve as an effective tool for statistically analyzing qualitative opinions and engaging different stakeholders, expert and non-expert alike, in the waste management decision-making process. Other institutions may choose this approach for decision making because it demonstrates integration of knowledge and ensures a transparent and holistic approach to waste management.

6.2.1 General recommendations

Based on the results of this study, general recommendations that will help guide institutions in understanding their existing situations, as well as identifying and selecting waste management options, include the following:

- **Complete bi-monthly audits on waste management invoice statements provided by external waste service haulers.** This ensures that the collection agreement is being upheld and that weight tickets are being provided. Without weight tickets, it is difficult to establish an accurate baseline of waste materials flow. Without an accurate baseline it is difficult to evaluate the successes and failures of a waste strategy and the implications of the various management practices. Audits of invoice statements also provide an institution with an overview of how much of its operating budget is spent on waste removal services and allows it to identify areas of inefficiencies. Regular audits of invoice statements represent an important part of an institution understanding its current situation, which ideally leads to a better understanding of the potential alternatives.

- **Review past waste characterization studies of material streams.** A document review of previous waste characterization studies is useful in providing insight into the actual state of the institution's waste management. It provides a reliable understanding of the material characterization of an institution's waste stream, including material types, generated quantities, and the contamination rates of particular streams. This knowledge is critical to the consideration of future waste management alternatives.

- **Apply a MCDA/ WSM framework for evaluating selected options.** The MCDA/ WSM framework can indicate the suitability of various waste management options while providing the insight necessary for an institution to make an informed decision that will likely have the support of the internal stakeholders involved in the institution's waste management operations.

- **Determine the key stakeholders that should be incorporated into the decision making process.** Engaging key stakeholders is vital not only for understanding an institution's current waste management practices, but also for understanding the feasibility of potential future alternatives/ considerations. Having different inputs from people who are actively involved in waste management activities at the university is important for the success and believability of the outcome. Stakeholders should be chosen based on their knowledge and experience in waste management, as well their position or role within an institution's practices. Important stakeholders to consider in the process include the following: custodial staff; municipal and provincial waste representatives/ experts; members of the student population; local residents of the area; and managers, administrators and directors of various departments within an institutions (such as finance, facilities management, procurement, etc.). Once selected, stakeholders will be responsible for selecting evaluation criteria, rating the importance of each criterion, and rating the performance of each option against the different criterion.

- **Determine the criteria for evaluating different waste management options within an institutional setting.** Using information found in the literature and input from key stakeholders, an institution can select a list of criteria that they wish to use when evaluating different options. The MCDA provides a holistic framework that can integrate conflicting, quantitative and qualitative components of a waste management problem. MCDA is intended to integrate criteria from four broad categories: environmental; economic; social; and health. Using these broad categories as a starting point, institutions should consult with stakeholders to determine which sub-criteria are applicable given the context of their problem. A list of criteria is presented in this study (Table 13) that other institutions may adopt or use as guidance in developing their own evaluation criteria.

6.3 Limitations Of Research

The focus group members purposively recruited consisted of waste management education and policy experts and Dalhousie waste management staff and administration. Representatives from the student population at Dalhousie, as well as local neighborhood residents who have to deal with the waste produced by the university, and waste engineers were not present at sessions. Involving these groups in future focus groups may reveal additional findings. The participants of the focus group sessions were guided through the rating process based on information provided to them by the primary investigator regarding each option's impact on the criteria. A criticism to this approach could be that the data and information provided to the focus group was not given to the members prior to the session (Hanan *et al.,* 2012), thereby preventing the members from reviewing the facts and verifying the accuracy of certain statements. Admittedly, the accuracy of using hard numbers in this research also proved to be a limitation. The cost data used for the construction of an on-site clean MRF and an off-site dirty MRF was based on costs from 1991, with an inflation calculator used to incorporate changes in inflation since 1991. However, even with this adjustment for inflation, the cost data used in this study for the MRF options is still not an accurate reflection of costs, as technology and its associated costs change over time.

6.4 Contribution To Practice

The research conducted in this study is timely because it comes at a point when Dalhousie University is working towards implementing a comprehensive waste management plan for Fall 2013. This research will be useful in assisting the development of such a plan, as it provides an understanding of current waste management practices at the university and highlights the environmental, economic, social, and health implications of potential alternatives. The outcome of the application of an MCDA/ WSM framework in this research demonstrates the utility of the various options and provides the insights necessary for Dalhousie to make an informed decision that will have a good chance of success and of acceptance by stakeholders.

6.5 Areas For Further Research

It is recommended that follow-up workshops be conducted in order to communicate the final results from the rating of each waste management option back to the stakeholders that contributed to the process. A platform to discuss the ranking order of waste management options would allow participants to share their opinions on the final ranking order and to discuss whether or not they agree with the end results. It would also be useful to have a workshop in which focus group participants could discuss their opinions regarding the overall MCDA process (i.e. criteria selection, weightings, and rating exercises) and suggest areas of improvement for further MCDA studies and for waste management decision making by HEI's.

Operational stages examined in this research included the collection, transportation, processing and disposal of waste management for each of the four major waste streams (fibre, recyclables, organics, and garbage). The remaining three streams (universal hazardous waste, hazardous waste, and construction & demolition waste) were not within the scope of this research, nor was the procurement stage. Extension of this work could provide further understanding of waste management at Dalhousie University by investigating the procurement stage, as well as the other three waste streams on campus. This study relied on the findings from a document review of past waste audits from 2008-2011 to better understand the characterization of waste streams on campus. Future research might include another campus wide waste audit in an effort to compare 2011 baseline contamination rates and quantities generated with more recent waste characterization data.

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Appendix A- Introductory E-mail for Participation in Interview Process

July 2011

Dear Mr./Miss___________,

My name is Chad Hiscock and I am a Master's student at Dalhousie University at the School for Resource and Environmental Studies. Supported by the Resource Recovery Fund Board (RRFB) I am completing a research study entitled: "Beyond 70%: Assessing alternative waste management opportunities for Institutions." I am conducting interviews to gain a better understanding of the University's current waste management system. I am also interested in finding out your opinion towards alternative waste disposal and diversion options that the University could potentially adopt.

Better understanding your opinions of Dalhousie's current waste management system and alternatives to waste disposal will be helpful in determining a new waste management plan for the University. This research project therefore aims to provide the University with a comprehensive waste management plan that incorporates the opinions and concerns of the numerous stakeholders involved, including you. These interviews are necessary to get more in-depth, face-to-face information to complete the research project. Your participation is integral to the project and development of a new waste management plan for Dalhousie University.

If you have questions about the research in general or about your role in the study, please feel free to contact me - Chad Hiscock - as per the information below. If you have any difficulties with, or wish to voice concern about, any aspect of your participation in this study, you may contact either Dr. Michelle Adams, the research supervisor, at (902) 494-4588, adamsm@dal.ca, or Catherine Connors, Director of Dalhousie University's Office of Human Research Ethics Administration, for assistance at (902) 494-1462, catherine.connors@Dal.Ca.

Sincerely,

Chad Hiscock
Principal Investigator
Dalhousie University
(902) 219-2864
chad.hiscock@dal.ca

Appendix B- Interview Questions

1. Do you think market opportunities exist for certain waste material at Dalhousie University? If so, what waste streams in particular and what kind of market opportunity?

2. Do you think it's both feasible and practical for a large institution, such as Dalhousie, to switch to a more 'in-house' set of waste management procedures? In other words, do you think it would be in the best interest for Dalhousie to begin handling or managing waste streams more internally and eliminate outside contractors/vendors?

3. What kind of changes could Dalhousie make to its current waste management system that would ensure higher waste/landfill diversion rates? Do you see any barriers to increasing landfill diversion rates at Dalhousie University?

4. Do you think Dalhousie should invest in different onsite technologies, such as compact waste balers, to handle particular waste material streams? What onsite technologies would you like to see explored more?

5. Are there any material streams that you think pose more of a challenge to handle internally than others? If so, which material stream(s)?

6. What kind of changes or stipulations would you like to see introduced into new contracts with outside vendors such as Re-group?

7. Do you think more education is needed at the University regarding the proper sorting of waste materials into the appropriate waste streams?

8. What ways could Dalhousie increase the efficiency of its current waste management system while minimizing environmental and economic costs?

9. What specific criteria would you like to see used when evaluating the performance of a waste management plan? (prompt: Green house gas rates, employment opportunities, health concerns, etc.)

10. Do you have any further comments or suggestions regarding current and/or future waste management practices at Dalhousie University?

Appendix C- Introductory E-mail for Participation in Focus Group

July 2011

Attention:

My name is Chad Hiscock and I am a Master's student at Dalhousie University at the School for Resource and Environmental Studies. Supported by the Resource Recovery Fund Board (RRFB) I am completing a study entitled: "Beyond 70%: Assessing alternative waste management opportunities for Institutions." I am conducting focus group sessions to gain a better understanding of the University's current waste management system and to identify the specific criteria you would like to see used when evaluating the performance of a waste management plan. I am also interested in finding out your opinion towards alternative waste disposal and diversion options that the University could potentially adopt.

Better understanding your opinions of Dalhousie's current waste management system and alternatives to waste disposal will be helpful in determining a new waste management plan for the University. This research project therefore aims to provide the University with a comprehensive waste management plan that incorporates the opinions and concerns of the numerous stakeholders involved, including you. These focus groups are necessary to get more in-depth, face-to-face information to complete the research project. Your participation is integral to the project and development of a new waste management plan for Dalhousie University. The date for the focus group is to be determined but the session will be approximately 1- 1.5 hours in length and will take place in the Central Services Building in room 511. Coffee, tea, and snacks will be provided!

Your time and willingness to participate in this research is greatly appreciated. If you have questions about the research in general or about your role in the study, please feel free to contact me - Chad Hiscock - as per the information at the bottom of the page. If you have any difficulties with, or wish to voice concern about, any aspect of your participation in this study, you may contact either Dr. Michelle Adams, research supervisor, at (902) 494-4588, adamsm@dal.ca, or Catherine Connors, Director of Dalhousie University's Office of Human Research Ethics Administration, for assistance at (902) 494-1462, catherine.connors@Dal.Ca

Sincerely,

Chad Hiscock
Principal Investigator
Dalhousie University
(902) 219-2864
chad.hiscock@dal.ca

Appendix D- Focus Group One Script

Focus group purpose statement:

To find out from faculty, staff, and waste management experts the specific criteria they would like to see used when evaluating the performance of a waste management plan. This focus group will be used in order to help identify criteria to be used in evaluation of different waste management processes at the University.

Focus group extra questions if needed

In the past illegal dumping has been observed on campus. What are your thoughts on this? Do you have any suggestions on how to monitor this type of activity?
Do you think the University should offer more education to its staff members regarding proper waste management? If so, what ideas do you have?

The opening (5- 10 minutes):

Welcome to the group, and thank you for joining us. My name is Chad Hiscock and I am a Master's student at Dalhousie University at the School for Resource and Environmental Studies. Supported by the Resource Recovery Fund Board (RRFB) I am completing a research study entitled: "Beyond 70%: Assessing alternative waste management opportunities for Institutions." Co-facilitating this focus group with me is Rochelle Owen, Director of the Office of Sustainability.

Today's focus group is one of two that are being conducted in order to gain a better understanding of the University's current waste management system and alternatives to waste disposal. This research project aims to provide the University with a comprehensive waste management plan that incorporates the opinions and concerns of the numerous stakeholders involved, including all of you here today.

The purpose of today's focus group is to identify specific criteria or indicators you would like to see used when evaluating the performance of a waste management plan. The criteria discussed here today will be used to evaluate Dalhousie University's current waste management practices and assess alternative processes that the University might be able to adopt. The main headings or categories that will be used include Environmental Impact, Economic Impact, and Socially Acceptable and Health Impacts. Some criteria might include things like time and costs for certain operations, smells, noise, jobs created and so forth associated with waste different management practices. Therefore, this focus group will be used in order to help different identify criteria/ indicators to be used in the evaluation of different waste management processes.

A focus group enables people to come together in one place to share their opinions on a topic. Each of you is representing your own opinions; you do not need to view your comments as representative of an organization or group of people. We would like to thank you in advance for your thoughtful consideration of our questions. It's important to note that your participation in this study is voluntary and you may withdraw at anytime. These focus groups are necessary to get more in-depth, face-to-face information to complete the research project. Your participation here today is integral to the project and development of a new waste management plan for Dalhousie University.

We will move through a series of questions and should be done in about an hour. Lets start by introducing ourselves.

The questions:

Question 1 (warm up questions) (3-4 min)

Do you think Dalhousie is 'over binned'? In other words, are there areas around campus that you think have more waste receptacles than are needed?

Question 2 (3-4 min)

Are there material streams on campus that appear to be more problematic than others when it comes to waste contamination? (prompts: coffee cups in wrong waste stream) If so, what material stream(s) appear to be more contaminated?

Question 3 (3-4 min)

Do you think Dalhousie should invest in different on-site technologies, such as compact waste balers, to handle particular waste material streams? What on-site technologies would you like to see explored more, if any? (i.e. balers, anaerobic digesters, other on-site composting technologies, different waste receptacles (bigger, smaller, more of, less of)

Question 4 (15 min)

What specific criteria/ indicators would you like to see used when evaluating the performance of a waste management plan? (prompt/ see list of prelim criteria: Green house gas rates, employment opportunities, health concerns, what things are going well with the current system and what things could be improved)

Discuss some of the categories and criteria already in consideration. Provide the major headings: Environmental Impact; Economic Impact; and Social and Health Impacts/ Ask participants what they think the strengths/ and or weaknesses of each criteria are. Use this opportunity to brainstorm ideas in-group discussion.

During discussion period, I will write down any additional criteria on handout sheet. A photocopy of this will be made with the additional criteria and then given out to the participants to rank. There will be a comment box if participants wish to comment but this is not mandatory.

Question 5 (10- 15 min)

Get participants to rank the importance of each of the criteria on a scale of 1 to 5, with 1 being 'Unimportant' 3 being 'Important', and 5 being 'Critical.' Bring back to a small group discussion.

What are your general impressions of the criteria?

Question 6 (5- 10 min)

Do you have any further comments or suggestions regarding current and/or future waste management practices at Dalhousie University?

The closing (5 min):

Thank you again for your participation. If you have questions about the research in general or about your role in the study, today or any days following, please feel free to contact you may contact me via e-mail or by phone, as indicated on the top of the project consent form. All of the information from this and other focus groups will be reviewed and summarized next month. It is my hope that a new waste management plan will be the result of this research and will be ready for review in the fall of 2012.

Appendix E- Preliminary Criteria List For Focus Group One

Table E. Preliminary criteria list for focus group one.

Comment Box (optional)	Rating Legend
	1 = Unimportant
	2 = Slightly Important
	3 = Important
	4 = Very Important
	5 = Critical
Criteria	Rating
Environmental Impact	
Landfill diversion rate (i.e. Recovery and reuse of materials	
Overall reduction of green house gases (GHGs)	
Enhance long term effectiveness	
Economic Impact	
Capital cost	
Operational/ ongoing costs (i.e. time, bags, bins, services, internal labour costs)	
Disposal costs/ market value for waste (i.e. Disposal tip fees)	
Payback period	
Socially Acceptable and Health Impacts	
Jobs created	
Educational benefits	
Injuries related to waste management practices (i.e. Throwing bags over shoulder)	

Appendix F- Example Scorecard Used In Focus Group Two

Organics		Options					
Criteria	**Weights**	**1 (Current)**		**2 (Onsite)**		**3 (Offsite)**	
Environmental Impact							
Landfill diversion rate	Critical	C		A		A	
Overall reduction of greenhouse gases (GHGs)	Important	C		A		D	
Enhancing sustainability (zero waste)	Critical	C		B		C	
Economical Impact							
Capital costs	Important	B		C		B	
Operational and disposal costs	Important	D		A		D	
Payback period	Critical	C		B		C	

Organics		Options					
Criteria	**Weights**	**1 (Current)**		**2 (Onsite)**		**3 (Offsite)**	
Social Impact							
Maximize educational benefits	Very important	C		B		B	
Maximize employment opportunities	Important	C		C		B	
Demonstrate community leadership	Critical	C		A		B	
Health Impact							
Minimize odours	Very important	A		B		D	
Minimize injuries related to waste management practices	Important	C		B		C	
Minimize noise and disturbances	Very important	D		B		D	

Appendix G- Qualitative And Quantitative Data For Each Option Against Evaluation Criteria

Organics	Waste Management Options		
Environmental impact	**Option 1 (Current)**	**Option 2 (Onsite)- In vessel digester**	**Option 3 (Offsite) – Agricultural College**
Landfill diversion rate	Some pre-sorting of material in warehouse before external waste hauler collects bins	Increased diversion rate due to essential pre sorting that is required for in vessel composter	Increased diversion rate due to essential pre sorting that is required for aerobic and anaerobic digestion at AC
Overall reduction of GHG's	Annual transportation emissions from Dal to Ragged Lake: 1601.75 tons CO2(e)	No transportation required offsite; transportation emissions negligible	Annual transportation emissions from Dal to Truro 7579.37 tons CO2(e)
Enhancing sustainability (zero waste)	Composting via aerobic at Ragged Lake for curing and stabilization; quality compost end result (6-7 mnths)	Closed loop system; produces quality compost; capacity for more materials to be diverted from landfill such as paper towel	Transportation of materials to NSAC not sustainable; quality compost produced

Organics	Waste Management Options		
Economical impact	**Option 1 (Current)**	**Option 2 (Onsite)- In vessel digester**	**Option 3 (Offsite) – Agricultural College**
Capital cost ($)	Equipment such as Schaeffer carts; transport bins	80,000 – 90,000 for in vessel composter	Aerobic costs to be shared with NSAC: 70,000 - 100, 000; WVO (proper storage containers): 9000
Annual operational and disposal costs ($)	46, 204 23 (includes lift and surcharge fee and disposal fee)	38,000 (includes labour costs of grounds staff to collect from sites and running costs)	40,000 – 65, 000 (includes labour costs) Transportation costs: approx. 12,000
Payback period	Reached	5- 7 yrs	>7 yrs

Organics	Waste Management Options		
Social impact	**Option 1 (Current)**	**Option 2 (Onsite)- In vessel digester**	**Option 3 (Offsite) – Agricultural College**
Maximize educational benefits	Events/ activities during or-week (waste sorting); student/employee waste materials guide	Hands on demonstration of technology (open to public); 'living lab'	Research opportunities for different composting techniques
Maximize employment opportunities	No new jobs created	Dedicated staff required to collect and transport stream from different sites to composter	Dedicated staff required to collect and transport materials to NSAC
Demonstrate community leadership	Excess food donated to 'Hopes Kitchen'; Use of local company for WVO removal	Extend life of landfills through increased public utilization of local composting facility	Selling of soil to local farmers in the Truro region

Organics	Waste Management Options		
Health impact	**Option 1 (Current)**	**Option 2 (Onsite)- In vessel digester**	**Option 3 (Offsite) – Agricultural College**
Minimize odours	No odours; organics removed from premises weekly	Zero odour guarantee; pest control	Odours resulting from aerobic composting practices; odours on highway
Minimize injuries related to waste mgmt	Potential for injury due to improper lifting techniques when collecting material	Control mechanism ensures no lifting > 25 pounds; reduces risk of lifting injuries	Potential for back injuries from placing full bins of material onto truck for transport to NSAC
Minimize noise and disturbance	Vehicular traffic on campus from external service haulers	No vehicle traffic from external service haulers	Vehicular traffic on campus from two Dalhousie fleet vehicles used to transport material

Paper/ cardboard	Waste Management Options		
Environmental Impact	**Option 1 (Current)**	**Option 2 (Onsite)- Compact waste baler**	**Option 3 (Offsite)- Shared dirty MRF**
Landfill diversion rate	Paper collected by staff and transported to MRF; cardboard collected by local hauler. Staff are not required to pre sort for contamination	Increased diversion rate due to on-site sorting of fibre before entering compactor; housed in warehouse	Front end sorting to increase diversion rate at dirty MRF (100 TPD), located offsite on property near pier, (S. end)
Overall reduction of GHG's	Annual transportation emissions from Dalhousie to transport paper to MRF (not included are emissions from waste hauler) 634.73 tons CO2 (e)	No transportation emissions associated with onsite baler	Annual transportation emissions from pier location to Scotia Recycling facility 984.85 tons CO2(e)
Enhancing sustainability (zero waste)	Pay for cardboard removal service, on-site shredding; transportation costs to MRF via Dal; inefficient process	Profit from sale bales to go back into recycling program (re-use of waste principle and reduce waste management costs)	Profit bales to go back into recycling program; maximize existing reuse efforts

Paper/ cardboard	Waste Management Options		
Economical impact	**Option 1 (Current)**	**Option 2 (Onsite)- Compact waste baler**	**Option 3 (Offsite)- Shared dirty MRF**
Capital cost ($)	Equipment costs such as Shaefer bins and (2x) vehicles used to transport: 75,000 – 80,000	Training and installation: 1000-2000; Scotia Recycling to provide baler free of charge	100 TPD Dirty MRF: 2,000,000 – 5,000,000 (costs divided equally among partners)
Annual operational and disposal costs ($)	103, 083	36, 900 – 40, 000	400,000 – 1,000,000 (costs divided equally among partners)
Payback period	Reached	1 yr (potential annual revenue of approx. 17,000)	30 - 65 yrs

Paper/ cardboard	Waste Management Options		
Social impact	**Option 1 (Current)**	**Option 2 (Onsite)- Compact waste baler**	**Option 3 (Offsite)- Shared dirty MRF**
Maximize educational benefits	Events/ activities during or-week (waste sorting); student/employee guide to recyclable materials; waste audits	Educational tours of facility	Educational center promoting sustainability at high level; tours of the facility
Maximize employment opportunities	No new jobs created	Recycling coordinator position; potential for student employment	Increased employment opportunities for at risk youth; employ local labour
Demonstrate community leadership	Participation in nation wide Waste Reduction Week events	First University in Canada to operate its own clean MRF	Community involvement and support integral to success; role model in sustainable waste practices

Paper/ cardboard	Waste Management Options		
Health impact	**Option 1 (Current)**	**Option 2 (Onsite)- Compact waste baler**	**Option 3 (Offsite)- Shared dirty MRF**
Minimize odours	No odours	No odours	Increased odour from dirty MRF operations
Minimize injuries related to waste mgmt	Potential for strain injuries from collecting and transporting paper	Minimal risk associated with operating baler	Risk of injury increases with automated machinery and industrial equipment; odours, dust and noise potential health hazards to workers
Minimize noise and disturbance	Waste hauler on campus weekly for cardboard removal; paper shredding companies idling issues	Reduced frequency of traffic on campus	Will not affect campus operations; public nuisance potential if noise not controlled offsite

Recyclables	Waste Management Options		
Environmental Impact	Option 1 (Current)	Option 2 (Onsite)- Clean MRF	Option 3 (Offsite)- Shared dirty MRF
Landfill diversion rate	Front end sorting by Youth Live ensures high diversion rate	Front end sorting by staff and students to ensure high diversion rate at clean MRF	Front end sorting by staff and Youth Live to ensure high diversion rate at dirty MRF
Overall reduction of GHG's	Annual transportation emissions from Dal to Youth live: 50 - 60 tons CO2(e) annually	No transportation to offsite MRF required	Annual transportation emissions from Dal to off-site MRF (near pier, s. end): 50- 60 tons CO2(e)
Enhancing sustainability (zero waste)	Refundable and non refundable items sorted accordingly; profit retained by Youth Live	Front end sorting; profit to enter back into campus Recycling Program	Refundable and non refundable items sorted accordingly; profit to enter back into program

Recyclables	Waste Management Options		
Economical impact	Option 1 (Current)	Option 2 (Onsite)- Clean MRF	Option 3 (Offsite)- Shared dirty MRF
Capital cost ($)	Equipment costs such as Shaefer bins and (2x) vehicles used to transport: 75,000 – 80,000	Clean MRF ≤ 10 TPD (tonnes per day): $200,000 to $900,000	100 TPD Dirty MRF: 2,000,000 – 5,000,000 (costs divided equally among partners)
Annual operational and disposal costs ($)	70,700 (approx.)	$100,000 – $150,000	400,000 – 1,000,000 (costs divided equally among partners)
Payback period	Reached	20- 40 yrs	30 - 65 yrs

Recyclables	Waste Management Options		
Social impact	**Option 1 (Current)**	**Option 2 (Onsite)- Clean MRF**	**Option 3 (Offsite)- Shared dirty MRF**
Maximize educational benefits	Events/ activities during or-week (waste sorting); student/ employee guide to recyclable materials	Begin participating in Recycle Mania annually; Campus Recycling program; offer academic credit; tour of clean MRF facility	Educational center promoting sustainability at high level; tours of dirty MRF facility
Maximize employment opportunities	Employment opportunities for at risk youth	Hiring of Recycling Coordinator	Increased employment opportunities for at risk youth
Demonstrate community leadership	Youth Live for front end sorting; engaging the community	Removal of Youth Live component; student employment/volunteer	Community involvement and support integral to success

Recyclables	Waste Management Options		
Health impact	**Option 1 (Current)**	**Option 2 (Onsite)- Clean MRF**	**Option 3 (Offsite)- Shared dirty MRF**
Minimize odours	Minimal odours from indoor or outdoor bins	Potential for odour; public nuisance tort	Odour control system required; potential public nuisance
Minimize injuries related to waste mgmt	Injuries resulting in lifting of recycling bags minimal; plastic gloves used	Manually sorting materials potentially resulting in repetitive strain injuries (Musculoskeletal injury)	ISO 14001 implementation of MRF; risk of injury associated with automotive equipment, fork lift; exposure to odours, dust and noise potential health hazards in dirty MRF
Minimize noise and disturbance	No external hauler used; minimal vehicle activity on campus	MRF located adjacent to warehouse; increased vehicular traffic on corner of Coburg and Oxford	Will not affect onsite campus operations; public nuisance potential if noise not controlled offsite

Garbage	Waste Management Options		
Environmental Impact	**Option 1 (Current)**	**Option 2 (Onsite)- Self contained compactor**	**Option 3 (Offsite)- Shared dirty MRF**
Landfill diversion rate	Difficult to determine accurately; invoice statements lack transparency and unclear	Remove standalone garbage bins & replace with 'Re-think' bins and 4 bin system; invoice transparency	Increased diversion through front end of materials sorting at dirty MRF
Overall reduction of GHG's	Annual transportation emissions from Dal to Otter Lake via external waste hauler: 4210.81 tons CO2(e) (@ 5 times per wk)	Annual transportation emissions from Dal to Otter Lake via waste hauler:: 2526.00 tons CO2(e) (@ 3 times per wk)	Annual transportation emissions from Dal to dirty MRF, MRF to Otter: 2000 to 3000 tons CO2 (e) (@ 3 times per wk minimum)
Enhancing sustainability (zero waste)	Green purchasing such as converting to EcoLogo certified products; Energy STAR Canada; Bookstore 'book-reuse' program	Contracts to contain language requiring vendors to help identify and minimize waste and maximize environment responsibility; centralized procurement	Maximize existing reuse efforts by front end sorting and therefore diverting recyclables, paper/cardboard, and organics from landfill

Garbage	Waste Management Options		
Economical impact	**Option 1 (Current)**	**Option 2 (Onsite)- Self contained compactor**	**Option 3 (Offsite)- Shared dirty MRF**
Capital cost ($)	Equipment costs such as Shaeffer bins; trucks used to transport to warehouse: 75,000 to 80,000	Outright purchase of 35 cubic yrd self contained compactor + insurance: 50,000 to 75,000	100 TPD Dirty MRF: 2,000,000 – 5,000,000 (costs divided equally among partners)
Annual operational and disposal costs ($)	160,000 to 170, 000 (invoice charges unclear)	110,728 (@ lift fee of 149.99 x 3 per week); Miller Waste would not provide specifics but willing to discuss options	400,000 – 1,000,000 (costs divided equally among partners)
Payback period	Reached	1- 4 yrs to recoup capital cost of purchasing compactor	30 - 65 yrs

Garbage	Waste Management Options		
Social impact	**Option 1 (Current)**	**Option 2 (Onsite)- Self contained compactor**	**Option 3 (Offsite)- Shared dirty MRF**
Maximize educational benefits	Events during O week (waste sorting exercise); planned events during waste reduction week; student/employee guide to waste management	Mandatory lectures on the importance of source separation; Recycling/ waste coordinator	Educational center promoting sustainability at high level; tours of dirty MRF facility;
Maximize employment opportunities	No new jobs created	Added responsibility for grounds staff to operate compactor	Increased employment opportunities for at risk youth; local labour potential
Demonstrate community leadership	Removal by local company (use of local labour/ services); participation in Waste Reduction Week	An example for other institutions to follow; pollution prevention policies emphasizing source reduction	Community involvement/ participation integral to success

Garbage	Waste Management Options		
Health impact	**Option 1 (Current)**	**Option 2 (Onsite)- Self contained compactor**	**Option 3 (Offsite)- Shared dirty MRF**
Minimize odours	Odours from loading bins minimal due to frequency of removal	Ozone odour and pest control;	Odour control system required; potential public nuisance
Minimize injuries related to waste mgmt	Back and arm injuries due to throwing bags over shoulders into loading bins (dumpsters)	Easy loading from either ground or dock level; level cart dumper system that allows Schaeffer carts to be lifted	Risk of injury associated with automotive equipment, fork lift; exposure to odours, dust and noise potential health hazards in dirty MRF
Minimize noise and disturbance	External hauler on campus daily for garbage removal; increased vehicular traffic	Some noise generated from on-site compactor; centralized drop off locations required	Will not affect onsite campus operations; public nuisance potential if noise not controlled offsite

Appendix H- Costs For Waste Removal Services

Table H. Total costs for waste removal services for the fiscal year April 2010- March 2011

Month (2010 – 2011)	Solid waste pick up fee (lift fee) ($)	Solid waste disposal ($)	Card-board lift fee ($)	Card-board disposal surcharge ($)	Organic cart exchange (lift fee) ($)	Organic disposal sur-charge ($)	Misc. items (C&D, yard waste) ($)	Total ($)
Apr.	3371.14	10824	608.96	176	1224.01	527	0	**16731.11**
May	3022.86	6842.2	581.28	168	286.21	124	0	**11024.55**
Jun.	3763.58	7693.45	608.96	176	586.84	244.9	0	**13073.73**
Jul.	4192.99	6866.2	608.96	176	1412.66	973.2	2366.8	**16596.81**
Aug.	3979.78	10303.5	608.96	176	641.15	254.2	3324.4	**19287.99**
Sept.	4333.9	9956.4	621.28	176	1526.64	623.1	3811.34	**21048.66**
Oct.	4097.09	4590.01	593.04	168	1896.36	771.9	2244	**14360.4**
Nov.	4077.14	19067	621.28	176	1882.58	771.9	4969.4	**31565.3**
Dec.	4418.51	8964.1	649.52	184	1607.82	662.5	2755.34	**19241.79**
Jan.	4748.6	9322.8	593.04	168	1812.76	740.9	1506.02	**18892.12**
Feb.	3817.37	8294.3	564.8	160	1822.02	750.2	1105.88	**16514.57**
Mar.	4326.34	11789	649.52	184	1817.33	744	2562.78	**22072.97**
Total	**48,149**	**114,512**	**7,310**	**2,088**	**16,516**	**7,188**	**24,646**	**$220,410**

*Does not include taxes or overdue payment fees

Appendix I. Current Costs Associated With Managing And Processing Recyclables Stream

Table I. Current costs associated with managing and processing the recyclables stream at Dalhousie University for the fiscal year April 2010 – March 2011. Cost is denoted by (-) and revenue (+)

Description	Capital cost ($)	Operating cost ($)
Operation and maintenance costs (annual)		
Grounds staff (x2) (labour) (1/3 FTE) = 2/3 FTE		-($30,000)
Vehicle (gas; upkeep)		-($700)
Subtotal	0	
Revenue (annual)		
Subtotal	0	0
Total (revenue- costs)		+(0) –(3700)
Final Total	**-($37,000)**	

Appendix J. Costs Associated With Managing And Processing Recyclables Stream On-Site Using 10 TPD Clean MRF

Table J. Potential costs associated with managing and processing recyclables stream on-site for Dalhousie University using a 10 TPD clean MRF (Adopted from Peer Consultants and CalRecovery, Inc., 1991, Handbook: Material Recovery Facilities for Municipal Solid Waste). Cost is denoted by (-) and revenue (+)

Description	Capital cost ($)	Operating cost ($)
Facility costs		
Construction costs	-($511,500)	
Engineering costs	-($102,474)	
Equipment costs		
Misc. conveyors	-($100,000)	
Sort conveyors	-($40,000)	
Sort platforms	-($60,000)	
Trommel screens	-($3500)	
Magnetic separators	-($7500)	
Subtotal	-($824,974)	0
Additional equipment associated costs		
Rolling stock	-($22,500)	
Installation (10%)	-($26,256)	
Contingency (10%)	-($31,132)	
Subtotal	-($79,888)	0

Operation and maintenance costs (annual)			
Labour (including sorters, Recycling coordinator, and other misc. labour costs)		-($93,600)	
Overhead		-($37,440)	
Maintenance		-($5850)	
Insurance		-($10,100)	
Power		-($2600)	
Water and sewage		-($55)	
Hauling/ fleet vehicle		-($701)	
Fuel for fleet vehicles and other misc. items		-($624)	
Subtotal		-($150,970)	
Revenue (annual)			
Refundable containers			+($15,000)
Subtotal	0		+(15,000)
Total (revenue - costs)			+($15,00) –($1,055,832)
Final Total	**-($1,054,332)**		

Appendix K. Current Costs Associated With Managing And Processing Organics Stream At Dalhousie University

Table K. Current costs associated with managing and processing organics stream at Dalhousie University for fiscal year April 2010 – March 2011. Cost is denoted by (-) and revenue (+)

Description	Capital cost ($)	Operating cost ($)
Operation and maintenance costs (annual)		
Lift fee (cart exchange)		-($16,517)
Surcharge fee		-($718)
Grounds staff (x2) (labour) (1/3 FTE) = 2/3 FTE		-($30,000)
Vehicle (gas; upkeep)		-($700)
Subtotal	0	-($47,935)
Revenue (annual)		
Subtotal		0
Total (revenue - costs)	0	**+(0) –($47,935)**
Final Total	**-($47,935)**	

Appendix L. Costs Associated With Managing And Processing Organics Stream On-Site For Dalhousie University Via In-Vessel Digester

Table L. Potential costs associated with managing and processing organics stream on-site for Dalhousie University via in-vessel digester. Cost is denoted by (-) and revenue (+)

Description	**Capital cost ($)**	**Operating cost ($)**
Processing equipment		
In vessel digester	-($87,595)	
Subtotal	-($87,595)	0
Collection and storage equipment		
20L UN Rated plastic pails for collection/ handling (x50)	-($617)	
Subtotal	-($617)	0
Operations and maintenance costs (annual)		
Running costs (including electricity and overall maintenance)		-($1080)
Grounds staff (x2) (labour) (1/3 FTE) = 2/3 FTE		-($30,000)
Vehicle (gas; upkeep)		-($1500)
Installation and training	-($2000)	
Subtotal	-($2000)	-($32,580)
Revenue (annual)		
Landfill tip fee savings		+($8750)
Subtotal	**0**	+($8750)
Total (revenue – costs)		+($8750) –($122,792)
Final total	**-($114,042)**	

Appendix M. Costs Associated With Managing And Processing Organics Stream Off-Site At The Agricultural Campus In Truro, NS Via Vermicomposting

Table M. Potential costs associated with managing and processing organics stream off-site at the Agricultural Campus in Truro, NS via vermicomposting (Adopted from Milnes, 2011, Environmental honours: A cost-benefit analysis of implementing a vermicomposting system at Dalhousie University, p.32). Cost is denoted by (-) and revenue (+)

Description	Capital cost ($)	Operating cost ($)
Equipment		
Continuous-flow vermicomposting reactor	-($50,000)	
Insulating polythene greenhouse-type tunnels	-($6666)	
Chopping/grinding/mixing machine	-($5000)	
Moving belts	-($1000)	
Earthworm waste separator	-($5000)	
Storage bays	-($1000)	
Subtotal	-($68,666)	
Operation and maintenance costs (annual)		
Labour		-($35000)
Energy		-($800)
Repair and upkeep		-($575)
Packaging		-($500)
Transportation costs		-($12,000)

Subtotal		-($48,875)
Revenue (annual)		
Landfill tip fee savings		+($8750)
Subtotal		+($8750)
Total (costs – revenue)		+(8750) -($117,541)
Final Total	**-($108,791)**	

Appendix N. Costs Associated With Managing And Processing Organics Stream Off-Site At The Agricultural Campus In Truro, NS Via Windrow

Table N. Potential costs associated with managing and processing organics stream off-site at the Agricultural Campus in Truro, NS via windrow. (Adopted from Center for Integrated Agricultural Systems, 1996, Windrow composting systems can be feasible, cost effective). Cost is denoted by (-) and revenue (+).

Description	Capital cost ($)	Operating cost ($)
Processing equipment		
Tractor and manure spreader	-($12,600)	
Front end loader	-($2750)	
Investment costs per cow for front end loader	-($256)	
Subtotal	-($15,606)	
Operation and maintenance costs (annual)		
Electricity and fuel ($5/hr.)		-($5000)
Annual land cost for compost site (2.1 acres) and costs of straw to mix with manure (per year for 60 cows at 1.81 kg/cow/day)		-($2450)
Cow		-($142/cow)
Subtotal		-($7592)
Revenue (annual)		
Landfill tip fee savings		+($8750)
Subtotal		+($8750)
Total (revenue - costs)		+($8750) –($23,558)
Final Total	**-($14,808)**	

Appendix O. Costs Associated With Managing And Processing Organics Stream Off-Site At The Agricultural Campus In Truro, NS Via Anaerobic Digestion

Table O. Potential costs associated with managing and processing organics stream off-site at the Agricultural Campus in Truro, NS via anaerobic digestion. (Adopted from Brown and Caldwell, 2008, Anaerobic digestion and combined heat and power feasibility study, p. ES 3 – ES 4)

Description	**Capital cost ($)**	**Operating cost ($)**
Processing equipment		
Anaerobic digestion	-($3,076,700)	
CHP system	-($1,480,300)	
Subtotal	-($4,557,000)	
Operation and maintenance costs (annual)		
Anaerobic digestion and CHP system		-($76,300)
Sludge disposal		-($43,700)
Net electricity use at $0.16/ kWhr		-($140,100)
Subtotal		-($260,100)
Revenue		
Landfill tip fee savings		+($8750)
Selling electricity to grid (Feed in Tariff)		Varies (depends on price paid per MWH)
Offsetting electricity and heat bills		$10,000
Subtotal		+($18,750)
Total (revenue - costs)	-	+($18750) – ($4,837,100)
Final Total	**-($4,818,350)**	

Appendix P. Current Costs Associated With Managing And Processing Garbage Stream At Dalhousie University

Table P. Current costs associated with managing and processing the garbage stream at Dalhousie University for fiscal year April 2010 – March 2011. Cost is denoted by (-) and revenue (+).

Description	**Capital cost ($)**	**Operating cost ($)**
Operation and maintenance costs (annual)		
Lift fee		-($48,149)
Solid waste fee		-($114,513)
Grounds staff (x1) (labour) (1/3 FTE)		-($15,000)
Vehicle (gas; upkeep)		-($700)
Subtotal		-($179,362)
Revenue (annual)		
Subtotal		0
Total (revenue - costs)		+(0) – ($179,362)
Final Total	**-($179,362)**	

Appendix Q. Costs Associated With Managing And Processing Garbage Stream On-Site For Dalhousie University

Table Q. Potential costs associated with managing and processing garbage stream on-site for Dalhousie University for fiscal year April 2010 – March 2011

Description	Capital cost ($)	Operating cost ($)
Equipment		
Recycling Stations (x24) - includes shipping and liners	-($52,498)	
Rebar concrete pad (10' x 30' x 10')	-($5000)	
Subtotal	-($57,498)	
Operations and maintenance costs (annual)		
Grounds staff (x3) (labour) (1/3 FTE)		-($45,000)
Vehicle (gas; upkeep)		-($700)
Compactor rental fee ($399.99 per month)		-($4,800)
Lift fee (149.99 x 3 per week)		-($23,398)
Otter Lake landfill disposal fee ($115.00 per tonne)		-($51,980)
Subtotal		-($125,878)
Revenue (annual)		
Potential savings resulting from on-site self-contained compactor (reduced lift and solid waste fees)		-+$35,000)
Subtotal		+($35,000)
Total (revenue - costs)		**+($35,000) –($183,376)**
Final Total	**-($148,376)**	

***Note:** If self-contained compactor is purchased outright, costs are approx. between $50,000 and $65, 000. A collection agreement would still be required with a local, servicing company. Not included in this table are the costs associated with renovations to warehouse space.

Appendix R. Weighted Score Tabulation For Recyclables Stream

Table R. Weighted score tabulation for recyclables stream.

Criteria	Weighting (w(j))	Waste management option		
		1.Business as usual	**2.On-site processing**	**3. Off-site processing**
Environmental impact		**1. BAU/ current** (w_{jBAU} a_{ij})	2. **Clean MRF** ($w_{jCM}a_{ij}$)	3. **Shared dirty MRF** (w_{jSDM} a_{ij})
Landfill diversion rate	0.36	0.36 x 4 = 1.44	0.36 x 5 = 1.8	0.36 x 5 = 1.8
GHGs reduction	0.29	0.29 x 4 = 1.16	0.29 x 4 = 1.16	0.29 x 4 = 1.16
Enhancing sustainability (zero waste)	0.36	0.36 x 3 = 1.08	0.36 x 4 =1.44	0.36 x 4 = 1.44
Economic impact				
Capital cost	0.25	0.25 x 4 = 1	0.25 x 1 = .25	0.25 x 2 = .50
Operational & disposal costs	0.33	0.33 x 4 = 1.32	0.33 x 1 = .33	0.33 x 2 = 0.66
Payback period	0.42	0.42 x 4 = 1.68	0.42 x 1 = .42	0.42 x 2 = 0.84
Social impact				
Maximize educational benefits	0.33	0.33 x 3 = 0.99	0.33 x 5 = 1.65	0.33 x 5 = 1.65
Maximize employment opportunities	0.25	0.25 x 4 = 1	0.25 x 4 = 1	0.25 x 4 = 1
Demonstrate community leadership	0.42	0.42 x 4 = 1.68	0.42 x 3 = 1.26	0.42 x 4 = 1.68
Health impact				
Minimize odours	0.36	0.36 x 4 = 1.44	0.36 x 3 = 1.08	0.36 x 3 = 1.08
Minimize injuries related to waste management practices	0.27	0.27 x 4 = 1.08	0.27 x 3 = 0.81	0.27 x 2 = 0.54
Minimize noise & disturbances	0.36	0.36 x 4 = 1.44	0.36 x 3 = 1.08	0.36 x 3 = 1.08
Total Score		**15.31**	**12.38**	**13.43**

Appendix S. Weighted Score Tabulation For Organics Stream

Table S. Weighted score tabulation for organics stream

Criteria	**Weighting (w(j))**	**Waste management option**		
		1.Business as usual	**2.On-site processing**	**3. Off-site processing**
Environmental impact		**1. BAU/ current** (w_{jBAU} a_{ij})	2. **In-vessel digester** (w_{jIVD} a_{ij})	3. **Agricultural Campus** (w_{jSDM} a_{ij})
Landfill diversion rate	0.36	0.36 x 3 = 1.08	0.36 x 5 = 1.44	0.36 x 5 = 1.44
GHGs reduction	0.29	0.29 x 3 = 0.87	0.29 x 5 = 1.45	0.29 x 2 = 0.58
Enhancing sustainability (zero waste)	0.36	0.36 x 3 =1.08	0.36 x 4 = 1.44	0.36 x 3 = 1.08
Economic impact				
Capital cost	0.25	0.25 x 4 = 1	0.25 x 2 = 0.50	0.25 x 4 = 1
Operational & disposal costs	0.33	0.33 x 2 = 0.66	0.33 x 5 = 1.65	0.33 x 2 = 0.66
Payback period	0.42	0.42 x 3 =1.26	0.42 x 4 = 1.68	0.42 x 3 = 1.26
Social impact				
Maximize educational benefits	0.33	0.33 x 3 = 0.99	0.33 x 4 = 1.32	0.33 x 4 = 1.32
Maximize employment opportunities	0.25	0.25 x 3 = .75	0.25 x 3 = .75	0.25 x 4 = 1
Demonstrate community leadership	0.42	0.42 x 3 = 1.26	0.42 x 5 = 2.1	0.42 x =1.68
Health impact				
Minimize odours	0.36	0.36 x 5 = 1.8	0.36 x 4 = 1.44	0.36 x 4 = 1.44
Minimize injuries related to waste management practices	0.27	0.27 x 3 = .81	0.27 x 4 =1.08	0.27 x 3 = .81
Minimize noise & disturbances	0.36	0.36 x 2 = .72	0.36 x 4 = 1.44	0.36 x 2 = .72
Total Score		**12.28**	**16.29**	**12.99**

Appendix T. Weighted Score Tabulation For Garbage Stream

Table T. Weighted score tabulation for garbage stream.

Criteria	Weighting (w(j))	Waste management option		
		1.Business as usual	**2.On-site processing**	**3. Off-site processing**
Environmental impact		**1. BAU/ current** (w_{jBAU} a_{ij})	2. **Self - contained compactor** (w_{jSCC} a_{ij})	3. **Shared dirty MRF** (w_{jSDM} a_{ij})
Landfill diversion rate	0.36	0.36 x 3 =1.08	0.36 x 4 = 1.44	0.36 x 5 = 1.8
GHGs reduction	0.29	0.29 x 3 = .87	0.29 x 4 = 1.16	0.29 x 4 = 1.16
Enhancing sustainability (zero waste)	0.36	0.36 x 3 = 1.08	0.36 x 4 = 1.44	0.36 x 4 = 1.44
Economic impact				
Capital cost	0.25	0.25 x 4 = 1	0.25 x 4 = 1	0.25 x 2 = .50
Operational & disposal costs	0.33	0.33 x 2 = .66	0.33 x 4 =1.32	0.33 x 2 = 1.32
Payback period	0.42	0.42 x 3 =1.26	0.42 x 4 = 1.68	0.42 x 2 = 1.68
Social impact				
Maximize educational benefits	0.33	0.33 x 3 =.99	0.33 x 4 =1.32	0.33 x 5 = 1.65
Maximize employment opportunities	0.25	0.25 x 3 = .75	0.25 x 3 = .75	0.25 x 4 = 1
Demonstrate community leadership	0.42	0.42 x 3 =1.26	0.42 x 4 =1.68	0.42 x 4 = 1.68
Health impact				
Minimize odours	0.36	0.36 x 3 = 1.08	0.36 x 4 = 1.44	0.36 x 3 = 1.08
Minimize injuries related to waste management practices	0.27	0.27 x 2 = .54	0.27 x 4 = 1.08	0.27 x 2 = .54
Minimize noise & disturbances	0.36	0.36 x 2 = .72	0.36 x 4 = 1.44	0.36 x 2 = .72
Total Score		**11.29**	**15.75**	**14.57**