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APPENDIX A

**COMPARATIVE ANALYSIS OF RECYCLING PROGRAMS:
A CASE STUDY OF THREE UNIVERSITIES
by**

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AN UNDERGRADUATE THESIS

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Abstract

The goal of this study was to conduct a comparative analysis of three university recycling programs. This study looked at several aspects of the programs that included the diversion rates, per capita ratios of materials recycled and disposed, and the average net costs of waste disposal and waste diversion. The universities included in this study were the University of Nebraska-Lincoln, the University of Colorado at Boulder, and the University of Oregon.

To gather the information necessary for this analysis, I contacted each of the university's recycling coordinators. To determine the average net costs of waste disposal and waste diversion I requested both the recycling budget and solid waste budget from each university for the fiscal years of interest which included: 2006-2007, 2007-2008, and 2008-2009. To calculate the diversion rates and per capita ratios, I requested performance records from each university listing the tonnage of materials recycled and disposed for the same years.

This study's findings reported that the average net costs for waste diversion in all three universities were \$22-\$122 less per ton than costs for waste collection and disposal. This study also indicated that the universities with the highest diversion and recycling rates were the University of Colorado at Boulder and the University of Oregon. The university with the lowest waste generated per capita was the University of Oregon followed by the University of Nebraska-Lincoln.

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Appendix B

Introduction

The Environmental Protection Agency estimates that the average American generates 4.6 pounds of municipal solid waste, otherwise known as “trash” every day. Ironically, this “trash” that by definition is “worthless material that is to be disposed of” does have an associated cost. Just ask any one of the several hundred universities that has to dispose of it.

Depending on which state you live in, commercial landfill tipping fees generally range from \$20/ton to \$70/ton. For universities these fees add up. In tipping fees alone the University of Oregon spends on average \$110,000/yearly. However, in the past few decades universities like the University of Oregon have found a way to divert nearly half of these \$65/ton tipping fees by recycling. Recycling programs offer universities both an environmentally and economically effective way to divert waste and tipping fees. Additionally, they also help offset operating and collection costs by generating revenue from goods sold.

This main objective of this study was to do a comparative analysis of three university recycling programs. The figures of interest in this study included: the average net costs of waste diversion and disposal, waste diversion rates, pounds recycled/ capita, and the waste generated/ capita.

The three universities evaluated included the University of Nebraska-Lincoln, University of Colorado at Boulder, and the University of Oregon. As a student at the University of Nebraska-Lincoln, I have always been interested in how recycling programs divert waste from going to the landfills and the net economic impact of this diversion. However, I recognize that in order to evaluate UNL’s program it is necessary to compare it to other university programs. As such, I have chosen to compare it to the University of Oregon and the University of Colorado. I chose the University of Oregon and the University of Colorado because they are known for their progressive steps towards recycling and effective waste diversion programs. Three other universities concentrated in the Big XII division were asked to participate in the study but never responded.

While this study seeks to accurately evaluate all of the university programs, study limitations do exist. This study was not comprehensive of all waste streams as it only examined the economic costs

of waste disposal and waste diversion via recycling. In addition, potential sources of error included: metric errors in weighed materials, volatilization of market commodity prices, insufficient record keeping, and basic time constraints.

With this study I attempted to gain a better understanding of the economic costs of waste diversion vs. waste disposal. In addition, I sought to better understand how recycling program dynamics (e.g. number of employees, funding, and type of system used) influence the amount of materials recovered. While this study seeks to contribute to the findings of other waste diversion studies, the main purpose of this information is to provide merit for the further development and expansion of university recycling programs.

Appendix C Literature Review

This section summarizes past studies that analyzed the estimated costs of waste disposal and diversion activities in various states. Most of these studies were case studies that compared the costs of collection and processing of recyclable materials with the costs of waste collection and disposal.

Deyle and Schade (1991) compared the long-term costs of city curbside recycling to that of waste disposal in landfills for four communities in Oklahoma. Their findings showed that net recycling costs (which include costs of collection and processing minus revenues from the sales of recyclables) were less than landfill disposal costs when the landfill tipping fees were more than \$35 per ton in the large cities and \$60 per ton in the small ones. A similar study by Folz (1999) reported that the average net costs for curbside recycling programs in 158 cities were \$30 less per ton than costs for waste collection and disposal.

Platt and Morris (1993) estimated the collection and disposal costs of residential waste in 15 different U.S. communities. Their study estimated the disposal costs were between the range of \$40 to \$170 per ton, while the net costs of source-separated curbside recycling collection were between \$35 and \$120 per ton. Overall, their findings suggested that net recycling costs were lower than disposal costs in most communities. However, they did note that recycling could be more expensive if communities had a low level of material recovery, low landfill tipping fees, and high startup costs.

Goldman and Ogishi (2001) conducted a comparative study of 6 economic regions in California to examine how diversion activities affected the regional economies. Their study showed that diverting waste has positive impacts on the California economy. In particular, their study illustrated that waste diversion creates jobs and adds economic value in regional economies. Their findings showed that, “only 2.46 jobs would be created for every 1,000 tons of waste disposed (1 job for every 400 tons), while 4.73 jobs would be created if the same volume of waste is diverted as recyclables (1 job for every 213 tons).”

A study in Washington (1992) documented the costs of residential curbside recycling versus disposal costs in four Washington State cities: Seattle, Spokane, Bellingham, and Vancouver. Based on the 1992 data, the study showed that “recycling can be less expensive than disposal, especially considering the revenues that

may be obtained from selling recycled materials.” They found disposal costs exceeded recycling costs from \$13/ton on the lower end in Spokane, to \$65/ton in Bellingham. Moreover, the study showed that even excluding revenue generated from selling materials, curbside recycling costs were still less than disposal costs in three of the four cities (Sound Resource Management Group, Inc., 1993).

Appendix D

Materials and Methods

During the spring of 2010, I gathered budget figures and recycling statistics from the University of Nebraska-Lincoln's recycling coordinator Prabhakar Shrestha, University of Colorado's recycling program advisor Jessica Bradely and coordinator Jack DeBell, and University of Oregon's recycling coordinator Karyn Kaplan. Following the initial collection of program recycling data, I then performed a series of analyses on the programs. The four figures of interest in this study included the average net costs of waste diversion and disposal, diversion rates (percent of materials recycled), pounds recycled per capita, and waste generated per capita.

To begin, I provide a brief introduction of each university's program criteria including: student population, number of recycling program employees, date of program inception, tonnage of recycled materials, yearly operating budgets, and the type of sorting system used (single stream vs. dual stream). Although not all the information is directly relevant to the analyses, I found it helpful to provide brief background information on each of the programs.

To determine the average net costs for waste diverted, I requested recycling budgets from the recycling coordinators at each university for the fiscal years of interest which included: 2006-2007, 2007-2008, and 2008-2009. I selected this time period because it was the most recent data available and because these years had large fluctuations in market commodity prices. This volatilization of commodity prices was important to include in the study because it helped determine if recycling was still cost-effective even during times of low commodity prices.

The total costs associated with each program included: the cost of equipment, transportation, collection, sorting, facility maintenance, and employee wages. After calculating the costs, I then subtracted the revenues generated from the total costs to determine the net costs of the program. To determine the average cost/ton of materials diverted I used the following formula: net costs/ total tons recycled.

To determine the average costs of waste disposed, I requested the solid waste operating budgets from each university. The total costs associated with solid waste disposal included: the cost of equipment, transportation, collection, facility maintenance, tipping fees, and employee wages. To

determine the average cost/ton of materials disposed I used the formula: total costs/total tons disposed. Note the key difference between costs of waste diversion vs. waste disposed. Diverted waste can generate revenue from the sale of recyclables; whereas disposed waste generates no revenue but instead incurs a tipping fee at the landfill.

One difficulty I encountered when examining all three university budgets was the fact that the solid waste budgets did not incorporate *all* of the associated costs of waste management. In particular, the budgets did not include the custodial costs of removing the trash from inside the buildings to the dumpsters outside. This was because custodial costs are often hard to document since the custodians duties are not just limited to trash removal. As a result, the custodians are not considered waste management employees and are instead paid under the general university's facility operating budgets.

To determine these custodial costs I asked the recycling coordinators to estimate what the custodial costs would be for only trash collection. These estimated custodial costs were then added to the university's solid waste budget which represented the total costs of solid waste collection. The criteria for determining the custodial costs included looking at how much time custodians spend per day/week/year for trash collection alone. The framework for determining these costs came from a 2007 study conducted by the University of Colorado that looked at the effects of not recycling on university custodians. The study determined that out of the 100+ custodians, the time spent on trash collection in academic/research buildings alone was the equivalent of 17 custodians, or about \$493,000 in salaries and benefits.

The second analysis metric looked at the diversion rates at each university. To calculate the diversion rates I divided the total tons of recycled materials collected by all waste materials and recycled material collected. Diversion rates illustrate the extent of which waste is diverted from landfills and instead recycled and are generally a good indicator of how effective a recycling program is at diverting wastes (University of Delaware, 2009).

The third analysis metric looked at the pounds recycled per capita. The per capita figure included the entire undergraduate and graduate student body, faculty, and staff. To calculate the pounds per

capita I used the formula: totals pounds recycled/ capita. This ratio is significant because it allows us to compare university recycling rates between universities regardless of their size.

The last analysis metric looked at the waste generated per capita. To calculate the pounds per capita I used the formula: pounds of waste land filled/capita. This study chose to examine the waste generated/capita because both waste reduction and recycling are key elements of campus sustainability. Moreover, this ratio is also significant because a small ratio often reflects a university-wide awareness of the importance the 3 R's: Reduce, Reuse, and Recycle.

Background Information

University of Nebraska-Lincoln

The University of Nebraska-Lincoln recycling program was established in 1996 and currently serves an approximate 28,000 students, faculty and staff. The university recycling program currently operates under the Landscape Services sector of Facilities Management & Planning.

At the advent of the program, the university allotted the program over \$100,000 in funds which included paying custodians for paper collection in all academic buildings. However, due to budget cuts in 2002, program funding was cut to \$67,000 a year which included eliminating the full-time recycling coordinator and the custodial paper collection in all academic buildings. Now, the only areas where custodians are paid to collect recyclables are in residential buildings. As a result of these budget cuts, the program now relies heavily on the volunteer efforts of students, faculty, and staff who pick-up recyclables from within academic buildings and transport them to recycling bins.

The program uses its \$67,000 in funds to cover vehicle operating costs and employee wages which include the part-time recycling coordinator and a full-time driver. Although there is some custodial help, custodial wages are not included in this budget for the following reasons: 1) custodial duties are not limited to recyclables collection; 2) custodians are paid under the general university facilities maintenance budget; 3) and custodial costs are difficult to estimate.

The university uses a multi-stream recycling technique which requires that materials be sorted depending on their source. This system is widely used because of reduced labor costs (i.e. little sorting required) and reduced rates of material contamination.

It should be noted that the university does have a few areas where recycling services are contracted out. As a result, the operating budget of \$67,000 is much lower than it would be otherwise. Hardin Hall (an academic building on east campus) and the Athletics Department have chosen to contract out for recycling services and therefore are not included in the university's recycling budget. The

university also has a contract with Pepsi (the on-campus beverage vendor) who is responsible for providing and emptying the recycling bins for plastic bottles in all academic buildings and the student union.

University of Colorado at Boulder

The University of Colorado at Boulder recycling program was established in 1976 and currently serves an approximate 32,500 students, faculty, and staff. The university recycling program operates under a partnership between the University of Colorado Student Union, Housing and Dining Services, and Facilities Management. The program is one of the oldest recycling programs in the country and has been nationally recognized by the National Recycling Coalition for its “cost-effective diversion of recyclables, promotion of recycling and resource conservation benefits, and opportunities for meaningful individual involvement.”

The program operates with a budget of \$402,000 which covers operating costs and the wages of the approximate 52 full and part-time employees who perform a number of tasks ranging from administrative duties, to materials handling and sorting. Many of the part-time employees are students who are involved in all parts of the recycling process beginning with outreach and education for the university community, to materials collection and sorting. Like the University of Nebraska-Lincoln, the program also uses a multi stream recycling method where materials must be source separated.

University of Oregon

The University of Oregon recycling program was established in 1989-1990 out of student grassroots efforts and currently serves an approximate 26,500 students, faculty and staff. Since its establishment in 1990, over 600 students have worked in the program as student recyclers. Student recyclers, who perform route collection, material processing, education and maintenance for over 1500 recycling and composting collection points on campus contribute greatly to the program. Of the 48 recycling employees, 42 are part-time student recyclers who clock 850+ hours per week to run the program.

The program has a budget of approximately \$650,000 a year, most of which covers wages. This funding comes from a variety of sources including the ASUO (the student government group), Facilities Services, student fees, and two other sources. Together, this funding has enabled the creation of an award

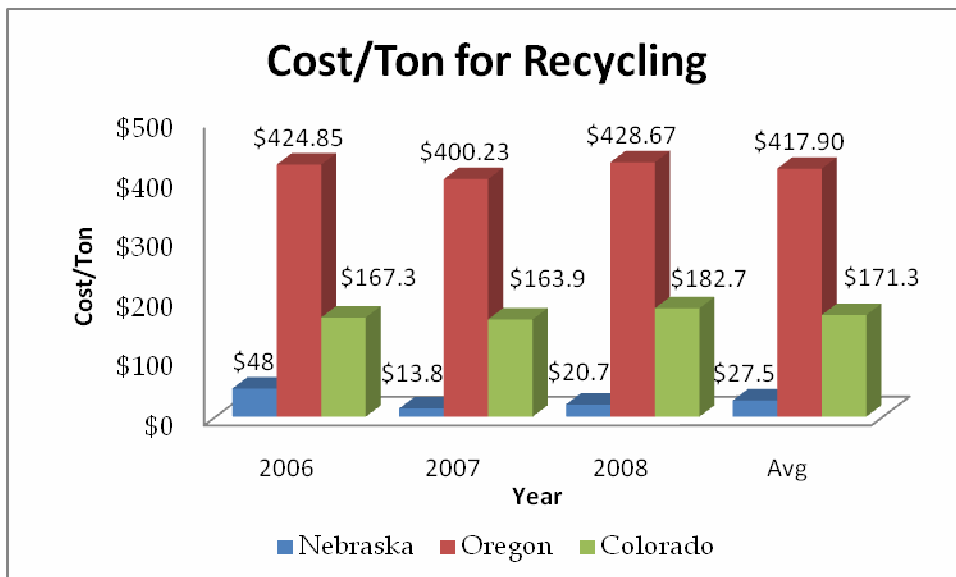
winning program. Since its inception the program has won over twenty local, state, and national awards for its commitment to sustainability. As a result of these efforts, the program currently recovers approximately 50% of the university waste stream through its recycling and composting efforts. The program currently uses a source separated system that accepts five grades of paper, bottles/cans, and compostable materials. The program doesn't believe in using a fully commingled system because of the high rates of material contamination and the labor intensive sorting process (Kaplan).

Appendix E Results

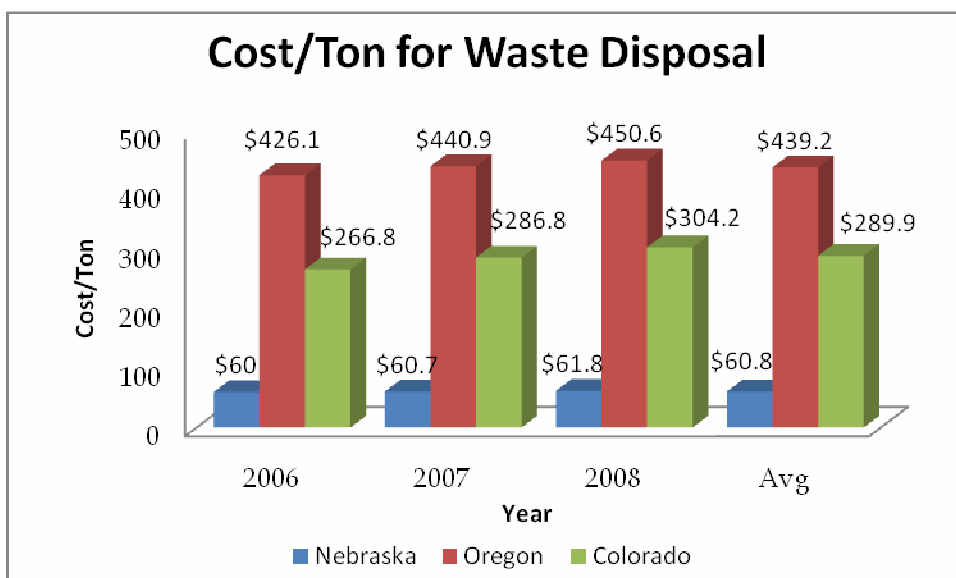
Cost/Ton for Recycling:

The following graph displays the average cost/ton of recycled and disposed materials. As the graphs indicate, the average net costs for recycling were \$22-\$122 less per ton than costs for waste disposal. The University of Nebraska-Lincoln had the lowest average costs for recycling and waste disposal, followed by the University of Colorado at Boulder. The University of Oregon had the highest average costs for recycling and waste disposal.

Graph 1: Cost/Ton for Recycling



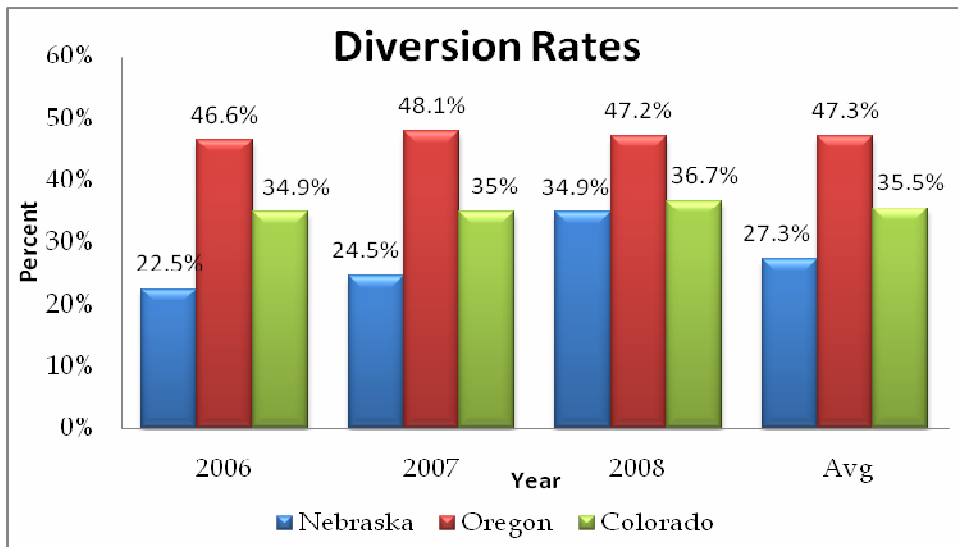
Graph 2: Cost/Ton for Waste Disposal



Diversion Rates:

The diversion rates are illustrated below in Graph 1. As the graph indicates, the University of Oregon had the highest and most consistent diversion rates averaging 47.3%. The University of Colorado-Boulder followed with a diversion rate averaging 35.5%. The University of Nebraska-Lincoln had the lowest diversion rates averaging 27.3%.

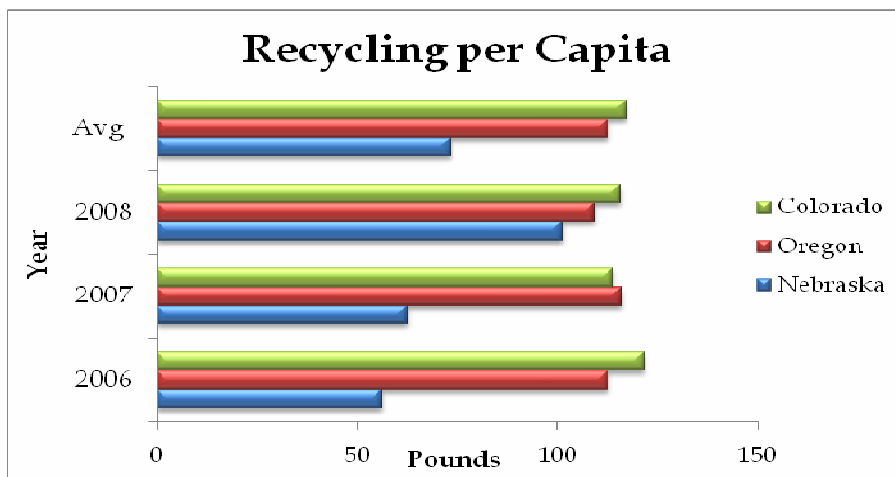
Graph 3: Diversion Rates



Recycling per Capita:

The pounds recycled per capita are illustrated below in Graph 2. As the graph indicates, the University of Colorado had the highest per capita recycling rate with an average of 117.1 over the three year period. The University of Oregon followed closely with an average of 112.7 pounds per capita. The University of Nebraska-Lincoln had the lowest per capita recycling rate with an average of 73.4 pounds.

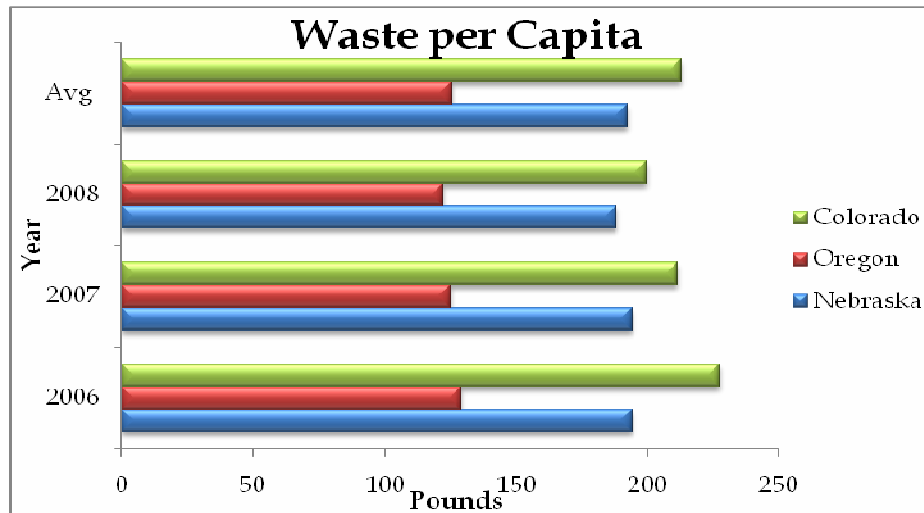
Graph 4: Recycling Per Capita



Waste per Capita:

The waste generated per capita is illustrated in Graph 3 below. As the graph illustrates, the University of Oregon consistently had the lowest waste per capita averaging 125.5 pounds per year over the three year period. The University of Nebraska-Lincoln followed with an average of 191.4 pounds per year. The University of Colorado had the highest waste per capita averaging 213.1 pounds per year.

Graph 5: Waste per Capita



Appendix F Discussion

Average Recycling and Waste Costs:

The results indicated that the average net costs for recycling were \$22-\$122 less per ton than costs for waste disposal. At all three universities, the average recycling costs were less than disposal costs. Furthermore, the data indicated that the University of Colorado at Boulder had the largest difference in net recycling and waste disposal costs which averaged about \$120 less per ton for recycling than for waste disposal.

In looking at Graphs 1&2, it should be noted that the University of Nebraska-Lincoln costs are significantly lower for several reasons including insufficient budget documentation and difficulty in determining custodial costs. If more accurate budget information were available these costs would be more comparable to the other two universities.

Diversification Rates:

Graph 3 indicated that the University of Oregon had the highest and most consistent diversion rates which averaged nearly 50% over the three year period. The University of Colorado at Boulder had the second highest diversion rates which averaged 35.5%. The University of Nebraska-Lincoln had the lowest diversion rates which averaged 27.3%. Despite trailing, the University of Colorado at Boulder and University of Nebraska-Lincoln appear to be increasing their diversion rates. It should be noted that the sharp increase in Nebraska's diversion rates between 2007 and 2008 can largely be attributed to on-campus construction and renovation projects. Construction companies who did the renovations were required to recycle all recoverable goods. As such, this increase is likely the result of campus construction efforts, not on-campus student efforts.

Recycling and Waste Per Capita:

Graph 4 indicated that the University of Colorado and the University of Oregon had the highest recycling per capita ratios. The University of Nebraska-Lincoln had the lowest recycling per capita which averaged 73.4 pounds. In looking at the correlation between the number of recycling program employees and funding, data indicated that the universities with the highest funding and most employees (Oregon and

Colorado) had the highest recycling ratios.

Graph 5 indicated that the University of Oregon had significantly lower waste ratios averaging 125.5 pounds. The two universities with the highest waste ratios were the University of Colorado at Boulder and the University of Nebraska-Lincoln.

Overall Conclusions:

This study's findings support past studies that indicated that average net recycling costs were less than disposal costs. This study found that in all three universities the average net recycling costs were lower than disposal costs. These findings suggest that waste diversion is more cost-effective than waste disposal even during times of commodity fluctuations. Furthermore, this study justifies the continuation and expansion of university recycling programs.

In looking at all three universities, it was evident that the University of Oregon and University of Colorado at Boulder were more effective at diverting their waste streams than the University of Nebraska-Lincoln. And although data indicated increasing trends in Nebraska's diversion rates, the university still has much room for improvement.

Suggestions:

The following is a list of suggestions to improve the recycling program at the University of Nebraska-Lincoln. The first suggestion is to explore new technologies such as reverse vending machines. Reverse vending machines that are strategically located in high traffic areas can eliminate the need for several recycling receptacles and also reduce labor collection costs. In addition, I strongly encourage administrative and staff members to improve their communication and record keeping amongst departments. This lack of communication and record keeping makes it very difficult to relay information amongst departments and between administrators and students. My last suggestion for the university is to consider introducing recycling curriculum into a mandatory freshman U101 introductory class. The curriculum would include basic ways to reduce waste (smart purchasing, reusing or fixing old goods, etc.) and familiarize students with campus recycling facilities and locations.

Appendix G

Tables

Table 1: Avg. Cost/Ton for Recy

2006	\$48	\$424.85	167.32
2007	\$13.82	\$400.23	163.93
2008	\$20.70	\$428.67	182.75
Avg.	27.5	\$417.90	171.33
	Nebraska	Oregon	Colorado

Table 2: Avg. Cost/Ton for Waste

2006	60	426.12	266.82
2007	60.72	440.91	286.822
2008	61.86	450.60	304.22
Avg.	60.86	439.21	289.95
	Nebraska	Oregon	Colorado

Table 3: Diversion Ra

2006	22.50%	46.60%	34.9%
2007	24.57%	48.10%	35.0%
2008	34.90%	47.20%	36.7%
Avg.	27.30%	47.30%	35.50%
	Nebraska	Oregon	Colorado

Table 4: Recycling per Capita

2006	56.2	112.8	121.8
2007	62.5	115.9	114
2008	101.3	109.5	115.7
Avg.	73.4	112.7	117.1
	Nebraska	Oregon	Colorado

Table 5: Solid Waste per Capita

2006	194.18	129.28	228
2007	194.18	124.95	212
2008	188.30	122.26	199.75
Avg.	192.22	125.50	213.12

	Nebraska	Oregon	Colorado
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Appendix H

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