A Feasibility Analysis Based on Locations Determination, Environmental Assessment and Economical Evaluation For Dual-Bins System

Final Report

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CEE 398 PBL

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Executive Summary

Recently, the University planned to replace the original One Bin System which collected garbage outside buildings with a dual bins system. Landfill bins which collect trash and recyclable materials were the only type of garbage bins to serve in the original one bin system. Therefore, some recyclable materials were polluted and not accepted by the factories which reused these materials. Eventually, these recyclable materials were discarded in the landfill, thus making the recycling rate low. To increase the recycling rate, the University introduced the dual bins system for collecting trash and recyclable materials in landfill bins and recycling bins individually. However, the University had not conducted any reports to determine the locations of the dual bins. This project aimed to determine the locations of the dual bins and calculate the investment cost and the future fees and revenue. With these calculations, our team calculated the space saving and payback period to determine the feasibility of the Dual-Bins System.

In this project, the pedestrian density was the key factor to determine the density of the dual bins. Due to lack of data, we evaluated the pedestrian density on campus with the student population in each school building. Some useful advice and resources were provided by experts in garbage management. The results of the questionnaire and relevant literature pointed out some common characteristics of the garbage bins' locations which became parameters used in location determination. All data was added into Geography Information System (GIS) to evaluate the pedestrian density. Eventually, locations of 161 dual bins are determined under the consideration of pedestrian density and area surrounding features. Moreover, the daily total garbage weight is 0.362 metric tons and the recycling rates before and after implementation of dual-bins system are 0% and 24.5% respectively. In other words, the trash is reduced 32 metric tons per year which can save 269 cubic meters of space in the landfill. To install this system, the University needs to spend $ 624,342 which takes 23 years to earn back. The average service life of dual bins is about 25 years which indicates the economic feasibility. Considering that the huge installation cost can prevent the University from implementing the system, ten dual bins were chosen as recommended locations to pilot the system.

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Introduction

With the development of people's environmental awareness, the concept of sustainability is gaining popular support. Zero waste, an approach to reduce, reuse and recycle waste to minimize the carbon footprint, has been embodied by policymakers around the world (Zaman, 2015). At the University of Illinois at Urbana-Champaign (UIUC), this commitment which serves as a component of the Illinois Climate Action Plan is of importance for achieving the carbon neutral target by 2050 (Facilities and Services University of Illinois Urbana Champaign, 2018). According to the data from Illinois sustainable technology center (ISTC) and our calculations, the waste generation weight outside the buildings on campus is about 795.04 pounds per day, in other words, 131.6 metric tons per year, and about 43% of them is recyclable materials. The lack of the recycling bins outside makes these valuable resources hard to reuse and they just go to the landfill (Illinois sustainable technology center, 2015).

Several methods can be used to solve this problem. Campus can concentrate more on the waste sorting process with the original one bin system. However, this method cannot make up the loss of recyclable materials which may be polluted by other waste. Placing several recycling bins for bottles, paper, metal, respectively also sounds good. But considering the extra expense on the waste transportation track and more sorting pressure on the students and school staff, it seems not the optimal choice. At present, single stream system is popular in United States. Single stream system refers to the idea that all the recyclable materials are collected in one bin and then sorted by the specialized waste sorting factory (Jamelske, 2006). Dual bins with two bins putting together, one for recyclable waste and one for landfill waste, are often used to achieve the single stream collecting. This system is more likely to be recommended for the campus, owing to existing waste sorting factory, less pressure on the current transport system and convenient waste dropping experience for staff and students (Jamelske, 2006).

Actually, the dual bins system has been implemented or pilot run in several universities in the United States like Harvard, Princeton and so on. For instance, the Princeton University launched a pilot single stream recycling program which implemented only two types of garbage bins in several dormitories. One type of garbage bin was for trash; the other was for the recyclable materials. The garbage going into the landfill decreased dramatically from 43% to 15% and the total recycling rate increased significantly from 57% to 85%, and these increments were for all kinds of recycled items including bottles, cans, metal and paper (Greening Princeton, 2013).

In fact, the single stream system is currently being vigorously promoted by the Facilities and Services, the Student Sustainability Committee and ISTC at UIUC: a pair of experimental dual bins which is convenient for the users and cleaners was set in front of the Altgeld Hall (Figure 1). The follow-up installation plan intending to remove all the original waste bins and install the new dual bins around campus has been proposed, however there is still a lack of information about the accurate installation locations of the dual bins and economic feasibility and environmental benefits of this system.

Figure 1: Dual bins installed near Altgeld Hall

This project determined the dual bins' locations and did the cost estimation and environmental assessments to help evaluate the feasibility of the project.

Objectives

This project aimed to determine the dual bins' installation locations and evaluate the feasibility of this system. The dual bins locations were ascertained by questionnaires investigation, model analysis based on ArcGIS Pro software and a field trip. A pilot project involving ten optimal bin locations were proposed. The feasibility analysis of this plan was mainly based on its economic feasibility and environmental feasibility. The determinations of the dual bins' locations and total numbers could provide the University of facilities and services concrete guidance for future implementation and the recommended pilot run could help the university to further test the applicability of the dual bins on campus. The estimations on the economic and environmental benefit of the dual bins system could strengthen the confidence of the university to install this system.

Methodology

In this project, determining the locations of the Dual Bins System was the major task and the pedestrian density was the determining factor in this task. Our team evaluated the pedestrian density with some subtasks, including consulting experts, conducting questionnaires and researching relevant literature. After collecting all the data, ArcGIS Pro software, one software with GIS, was used to analyze and determine the locations and the total number of the dual bins. In addition, with data in "Quad Recycling Containers Implementation Project," the total garbage weight and recycling rate were estimated which were used to evaluate the environmental effects. Moreover, unit prices of recyclable materials and trash were used to estimate the future fees and revenue. Combining these estimations with the investment of the dual bins, the payback period was calculated.

Task 1 – Determine the location and the total number of dual bins

There were two assumptions in this task. First, places with high pedestrian density can generate large amounts of garbage which indicated that these places need more bins to collect garbage. Therefore, the density of the dual bins is proportional to the pedestrian density. Due to lack of pedestrian density data, here is the second assumption to help evaluate the density: the pedestrian density is high near the school buildings, as most students move to their classes by walking.

Evaluation of pedestrian density

At the beginning, questionnaires were conducted which helped to determine the dual bins' density directly. However, due to limited data, the result did not attain the expectation, instead some common characteristics of the locations were noticed. After consulting Morgan White, Associate Director in Service and Facility, our team used the pedestrian density to evaluate Dual Bins' density based on two assumptions mentioned above. Therefore, the total student population in each school building was used to evaluate the pedestrian density. To know the statistic, the student enrollment in each department was assigned to the school building where the department was located. Additionally, the student enrollments of different departments in the same school building combined. With Google Maps, the longitude and latitude of each school building were collected. Also, some relevant literature was reviewed to get some parameters to determine bins' location in similar cases.

Determination of locations and total number of dual bins

We added the student population in each school building into ArcGIS Pro to evaluate the pedestrian density. Based on the density, we determined the primary locations. In addition, it is better to install dual bins in the certain environment. For example, the place with concrete pavement is a good choice, because the University does not need to add extra concrete pavement to install the dual bins which can save the installation cost. Also, the dual bins on the concrete pavement are easy to maintain. Therefore, considering certain environment, a field trip found out the best place within the area which was assigned a pair of dual bins. Google Maps was used again to locate dual bins. After determining the locations, the total number of the dual bins was known.

Task 2 – Estimate the effect on the environment

There were two assumptions in this task. First, the garbage in the landfill bin could not be recycled. Although some recyclable materials in the landfill bin may be recyclable originally, the factories which bought recyclable materials did not buy polluted ones. Eventually, these recyclable materials were discarded into the landfill. To make the calculation easy, here was the second assumption: the composition and the total amount of the garbage did not change.

Using the data in "Quad Recycling Containers Implementation Project", a report which recorded the procedure and the result of the dual bins' pilot run on the quad, the current and the future recycling rate and the total garbage weight were estimated and calculated. With these data, the trash reduction and the increase of recyclable materials were known. Furthermore, the data from the relevant literature could know how much land space could be saved if recyclable materials were reused.

Task 3 – Estimate the investment, future fee and future revenue

The installation cost of the dual bins was the investment of the dual bins system. The total number of dual bins multiplied by the unit price of the dual bins is the value of the investment. The trash weight multiplied by unit disposal fee is the future fee, which the University needs to pay to the landfill to deal with the trash. In addition, the University can earn revenue by selling recyclable materials. With these three values, the payback period was estimated to address the economic feasibility.

Results and Discussion

<u>Locations determination</u>

Data collection

Figure 2 shows the locations that people chose on the questionnaire map and Figure 3 gives us a close look at the choices and their characteristics. According to the data collected by questionnaires, some common characteristics of the locations were noticed as shown in Table 1: the recommended locations are on the intersection or near the school buildings, bus stops, restaurants and other active areas. This analysis gave this project some clues when determining the locations of the dual bins.

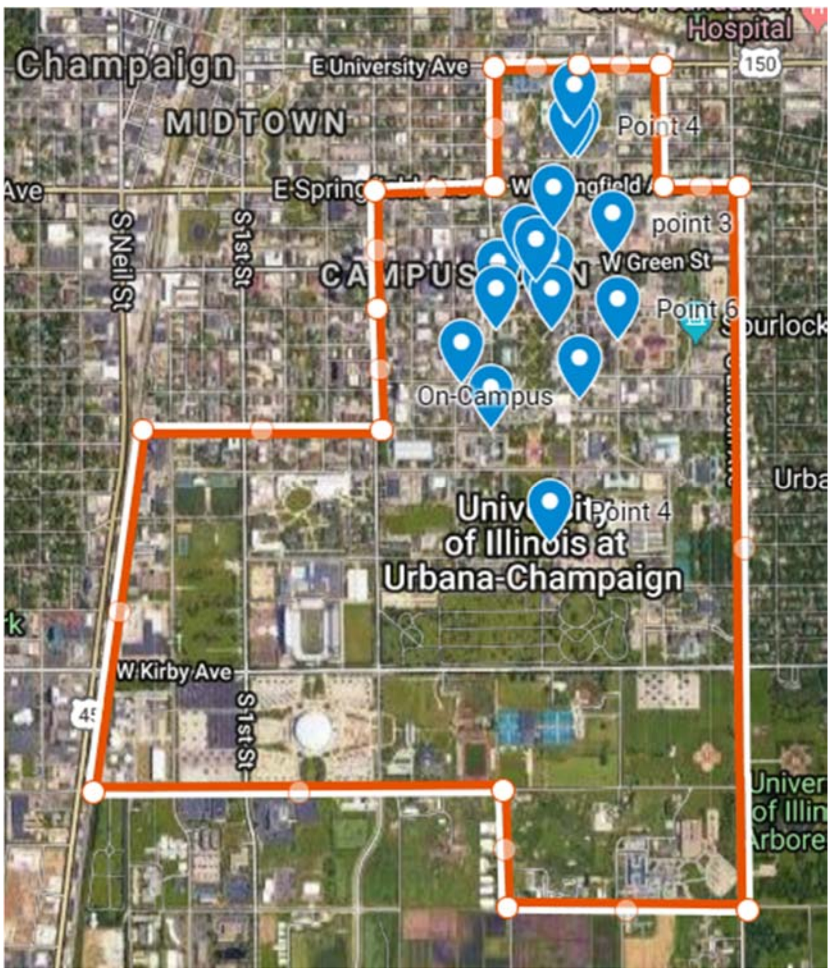


Figure 2: The dual bin locations which people chose in the questionnaires

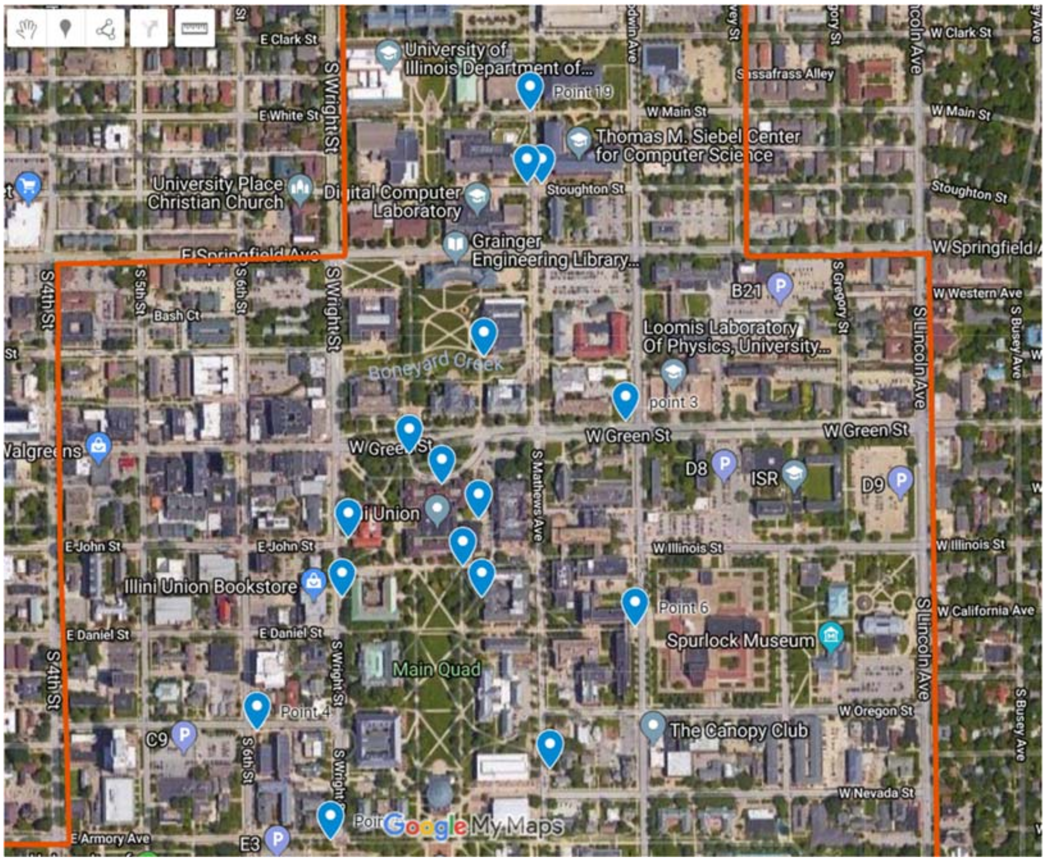


Figure 3: A close look at Figure 2

Table 1: The category of the points

Total point	**18**
Intersection	8
School Buildings	16
Bus Stop	7
Restaurant	5
Quad	5

The student population in each department was collected from the report "UIUC Student Enrollment by Curriculum and Student Level" found from the website of Division of Management Information in the university (). The numbers of the students in each dormitory were achieved from the university housing project manager Mr. Johnson. The longitude and latitude information for these department buildings and dormitories were determined by google map. There are statistics for the 58 departments and 22 dormitories shown in Appendix A and B.

Data analysis

After the data collection, the information about the student numbers in each department building and dormitory was added into the ArcGIS Pro software. The purple dots determined by the longitude and latitude on Figure 4 represent the department buildings and dormitories and the red line represents the boundary of the university. To determine the pedestrian density near the buildings, spatial interpolation which can estimate the values of properties at unsampled sites within an area covered by existing observations is used. Based on the assumption that the buildings capacity can affect the pedestrian density near these buildings, inverse distance weighted interpolation (IDW) method is introduced to this project. IDW assumes that the value of the unknown point is more affected by the value of the closer known point than those of the far points, and the influence degree is inversely proportional to the distance. The different color lines represent the contours result of the interpolation. The area inside the orange line represents the most crowded area and the green one is the next and the blue one is the last. The north part of the campus has the enough statistics while the south part is occupied by athletic facilities and agricultural facilities in this way lack of data, so the determination of the dual bins' locations only processed for the north of Kirby street in Champaign.

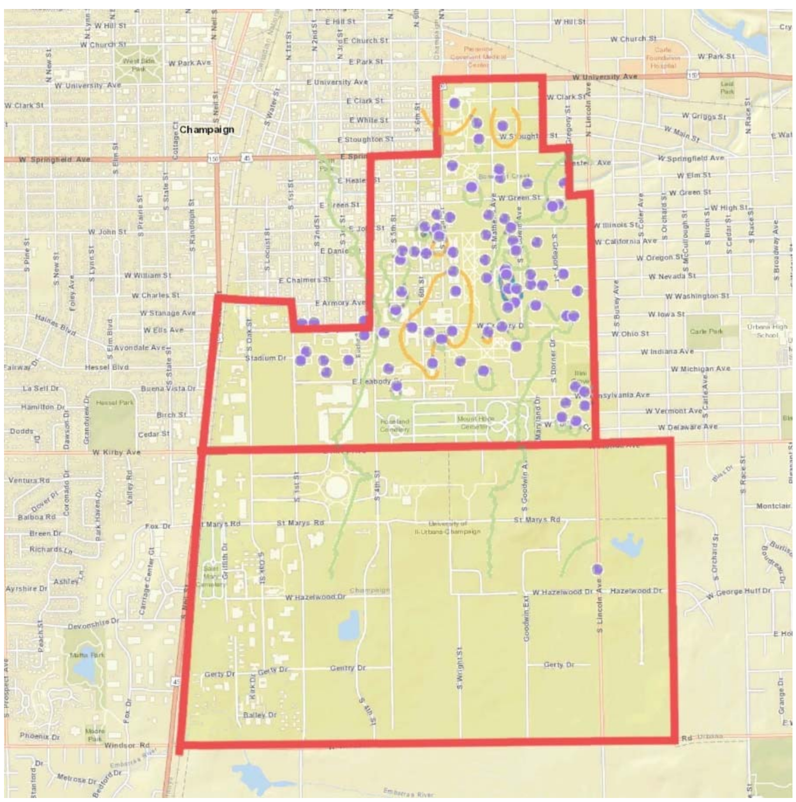


Figure 4: The interpolation results reveal the possible visitor flow

According to the relevant literature, the distance between each bin in urban areas is 100 meters to 180 meters (Erfani, Seyed Mohammad Hassan, et al 2017). Denser pedestrian flow means more waste generation and more dual bins are required. On the map, the departments or dormitories (the red points on the map) serve as the circle centers and the circle is drawn every 100m for the most crowded area as shown in Figure 5, 150 m for the less crowded area and 180 m for the least crowded area.

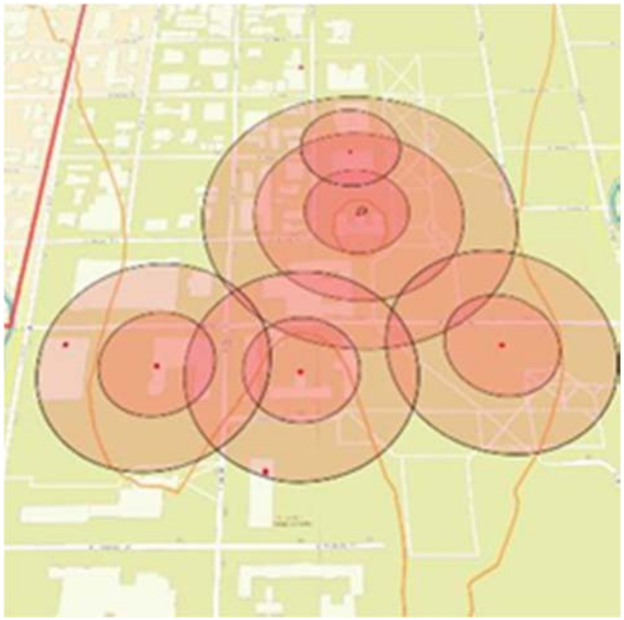


Figure 5: Sketch map for determining the possible locations determination

In this way, there are so many locations to place the dual bins. Further, the crossing become the most appropriate choice because it is easy to see the dual bins from different directions and the questionnaire research results also show the intersections are recommended locations. The final locations determined by comparing the possible locations on the circles and crossing on the word street base map. Taking the area in the Figure 6 as an example, the blue star marks represent the final dual bins locations.

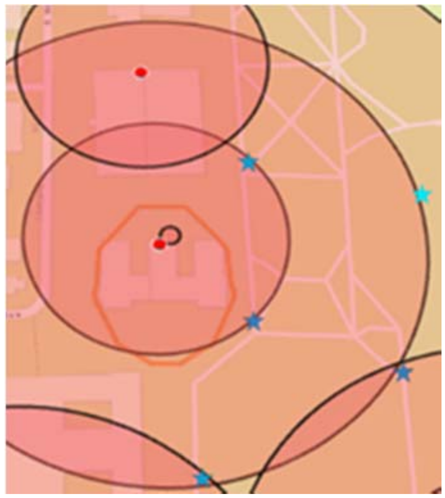


Figure 6: Sketch map for determining the locations according to the crossing

After the determination of dual bins location on the GIS software, these locations were reconfirmed through a field trip and then we knew the basic condition of the locations. The final locations are shown in Figure 7. The relevant information is included in Appendix C. The recommended number of dual bins is 161. 102 of them need a concrete base for the installation of the dual bins, 108 of them are on the intersections which means they are more noticeable and 34 of them are near the bus stations where are not controlled by the University Facilities and Service, which means further discussion with MTD company.

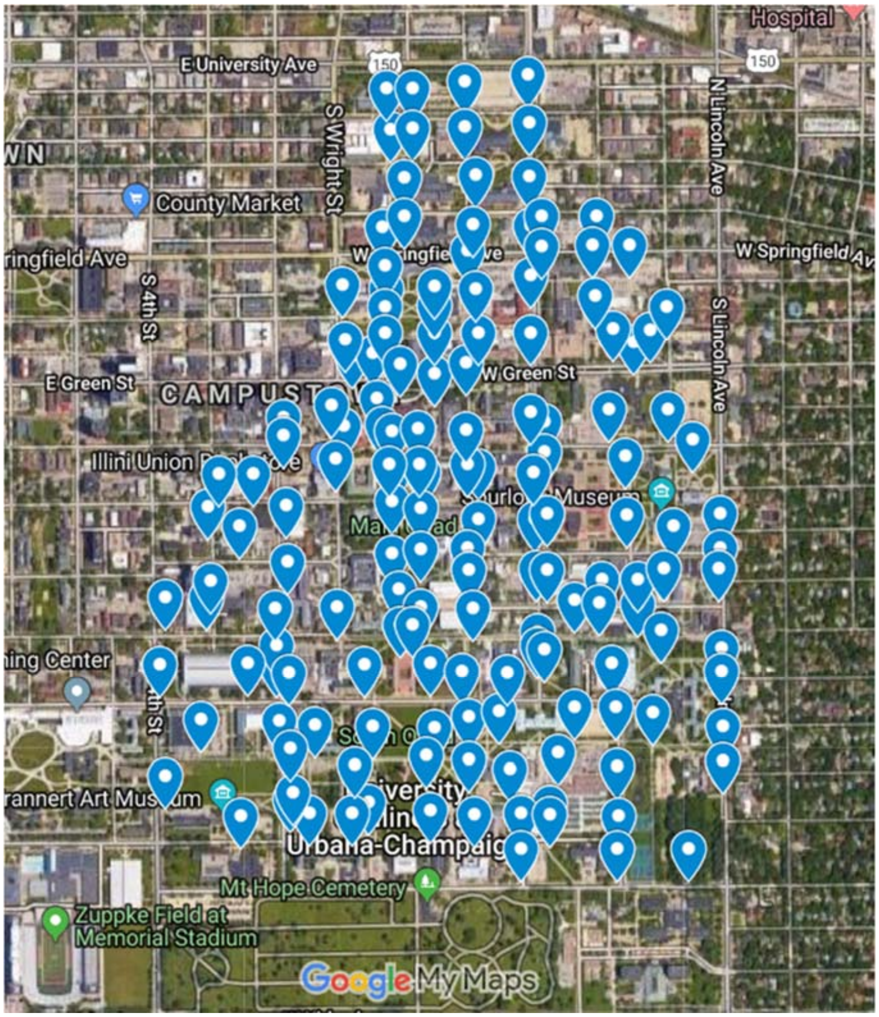


Figure 7: The dual bins locations on Campus

All these locations were also compared with the underground installation situation by F&S GIS manager and the detailed information about the potential conflicts between the installation of the dual bins and existing pipes were shown. But considering there are only some concrete bases need to be paved and no destructive damage to underground infrastructures, current recommendations of the locations are acceptable while it will be better to avoid installing the dual bins directly above the pipes so that it is more convenient for the maintenance of the pipes.

Then a pilot run was proposed to avoid a large investment at a time. Ten locations were included in the pilot run as shown in Table 2. All these chosen locations are at a crossing with concrete base and are controlled by Facilities and Service Department so that they may have the best performance of recyclable wastes collecting. Meanwhile the locations in pilot run are evenly distributed across the campus so that the pilot run results can reveal the real situation around the campus.

Table 2: The selected locations of pilot run dual bins (Site ID is same with Appendix C)

Site ID	Latitude	Longitude
8	40.11459	-88.2241
28	40.11045	-88.2287
35	40.11061	-88.2241
43	40.10919	-88.229
50	40.10689	-88.2314
53	40.10531	-88.2305
87	40.10907	-88.2241
99	40.10703	-88.2254
123	40.10141	-88.2243
152	40.1033	-88.221

Estimation of environmental impacts

Calculation of the total garbage weight and recycling rate

In the report "Quad Recycling Containers Implementation Project," the Illinois Sustainable Technology Center demonstrated the procedures and the result of the pilot run of dual bins on the Quad. In this report, the garbage was classified into three categories, including "Bottles and Cans", "Recycled in the community" and "Landfill". The "Bottles and Cans" category included #1 and #2 plastic bottles — PET (Polyethylene Terephthalate) and HDPE (High-Density Polyethylene) — and aluminum cans. In addition, in the "Recycled in the community" category, some materials which could be recycled by Urbana's U-Cycle Program were included. Therefore, the "Landfill" category included remaining garbage. There were 27 locations which were chosen to add the dual bins. These dual bins were measured regularly to get the weight of landfill bins and recycling bins individually. Moreover, the report illustrated the diversion rate that each category accounts for (Illinois Sustainable Technology Center, 2015). Diversion rate is the ratio of amounts of certain material to sum total of each category's weight. Based on the data provided by this report, the weight of each category in each bin is calculated and shown in Appendix D.

The original bins are located at 133 locations. Based on assumptions which are mentioned in Methodology Task 2, the total amount of the garbage does not change. In addition, the average garbage weight in each bin shown in Appendix D is 5.98 lb/bin. Therefore, the total amount of the garbage is $0.361 \text{ metric tons}$. Table 3 shows not only the total weight of the garbage but also recycling rate and each category's diversion rate. Recycling rate is the sum of the diversion rates of “Bottles and Cans” category and “Recycled in the community” category.

Table 3: Total amount of the garbage, the recycling rate and the diversion rate before and after implementing the dual bins system

	Total amount of the garbage (metric ton)	Recycling rate	Diversion Rate		
			Bottles and Cans	Recycled in the community	Trash
Before	0.361	0%	0%	0%	100%
After	0.361	25%	17.2%	7.3%	75.5%

With the results in Table 3, the reduction of the trash can be calculated. Before implementing dual bins system, the trash weight is 0.361 metric tons. However, after implementing, the trash weight is 0.273 metric tons which reduces 0.088 metric tons. In addition, the weight in the “Bottles and Cans” category and “Recycled in the community” category increase to 0.062 and 0.026 metric tons individually. In other words, the weight of recycled material increases to 0.088 metric tons.

Environment impact evaluation

In UIUC, all the trash is transported to a landfill (University of Illinois Facilities and Services,2018). Leachate containing poisonous organic and inorganic compounds is one of the most serious problems caused by landfill. It can pollute the soil and more seriously leachate sometimes goes into the groundwater which poses a risk to the ecosystem and human health around these areas (Ravindra,2006). Meanwhile the natural gas, one type of greenhouse gases which is also generated by the landfill, can accelerate the global warming (Allen, 1997). Except these problems, landfill also takes up a lot of land. According to the calculation before, we figured out that using the dual bins can reduce about 32 metric tons per year waste going into the landfill. According to the report of the US Environmental Protection Agency’s (USEPA), the compaction estimate in the landfill is 118.65 kg/m^3 for mixed waste (USEPA, 1994), that means 269 m^3 land can be saved every year.

In other words, about 32 tons recyclable materials will be reused every year. Recycling means less energy consumption and resources waste. we should notice that the recycle rating in our project is only 24.5%. As mentioned in the introduction, about 43% of the waste is recyclable materials, moreover, there is 18% waste we can also reuse by improving students’ sense of sorting.

Estimation of the economic feasibility

Unit installation cost estimation

According to the installation cost calculation for the established dual bins near Altgeld hall from Ms. White as showed in Table 4, the total unit cost is $3877.9, where the iron workers' fees and the material cost account for most of the expenses. There would be some discount for bulk installation.

Table 4: The unit cost for dual bin

TASKS	COST/BIN
Iron Workers	$1,014.02
Cement Finishers	$230.45
Laborers	$466.08
OE's (Labor)	$220.08
OE's (Equipment Charge)	$120.00
Transportation (Labor)	$200.00
Transportation (Equipment Charge)	$25.00
Painters	$296.22
Service Contract Management	$106.05
Material cost for 2 cans ($600 each)	$1,200.00
Installation total	$3,877.90

Calculation of future fee, revenue and payback period

The current unit prices of recyclable materials are shown in Table 5. Although the garbage classification is simple, there is a lot of unknown data, including materials in the "Recycled in the community" category and percentages that each materials account for in each category. Therefore, there are some assumptions to calculate the rough unit price of each category. Assume that percentages of PET bottles, HDPE bottles and aluminum cans are the same and the paper is the only thing except bottles and cans that students throw outside the building. In other words, the "Recycled in the community" category includes only paper. Based on these assumptions, the unit price in each category can be calculated and presented in Table 6. These unit prices indicate the revenue and fees which the University can earn or pay from each category. Among them, the unit price of the "Bottles and Cans" category is the average price of the aluminum cans, PET bottles and HDPE bottles.

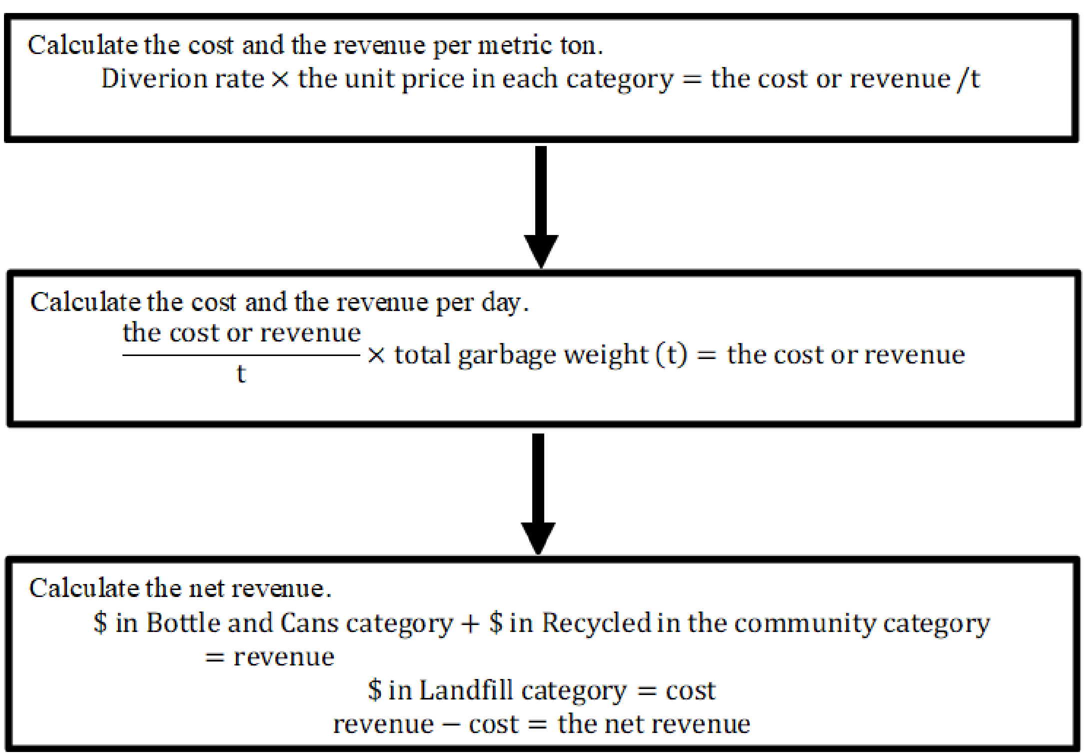
Table 5: The current unit prices of recyclable materials

	Aluminum Cans	PET Bottles	HDPE Bottles	Paper (mixed)	Trash
$ / metric ton	$ 992.08	$ 1,135.38	$ 1,322.77	$ 68.50	$ 25.32

Table 6: The unit price in each category

	Bottles and Cans (Revenue)	Recycled in the community (Revenue)	Trash (Fees)
$ / metric ton	$1,150.08	$68.50	$25.32

The University pays fees to the landfill to deal with the trash which considered as the outcome of the dual bins system. However, the University can sell the recyclable materials to earn some revenue, the income of the dual bins system. In addition, the installation cost of the dual bins is considered as the investment cost. Based on the value in Table 3 and Table 6, the cost and revenue can be calculated. Picture 8 is the explanation of the calculation.



Picture 8: The explanation of the calculation

Moreover, the cost of constructing a pair of dual bins is $ 3877.90 and the total quantity of dual bins is 161. Therefore, the value of the investment is $ 624,341.19. From Table 6, the difference between the net revenue is $ 27,568.46, an extra revenue which the University can earn after implementing the system. In conclusion, the University needs to spend 23 years to earn its investment. The average service life of bins is about 25 years. Moreover, the recycling rate increases year after year and if many dual bins are installed in the same time, the installation cost will reduce. In other words, the University can earn more money in the future, and it can earn its investment less than 23 years.

Table 7: Cost and revenue annually

	Bottles and Cans	Recycled in the community	Trash	Net Profit
Before	$ -	$ -	$ 3,332.83	-$ 3,332.83
After	$ 26,093.42	$ 657.53	$ 2,515.32	$ 24,235.62

Although the system is economic feasibility, the significant amount of investment cost can prevent the University from implementing the system. Despite the University had piloted Dual-Bins system on the quad, it did not have the enough data and information to predict the Dual-Bins System's impaction on whole campus. Therefore, ten places were chosen as test places to pilot the system. The total installation cost of these ten pair dual bins is $ 38,779. These dual bins can collect garbage in different areas. The characteristics of garbage can be analyzed to develop more precise locations and predict more accurate environmental and economic assessment.

Conclusions

The waste generation outside the buildings on campus weights about 131.6 tons per year and 43% of it is recyclable materials. At present, there is a lack of outdoor recycling bins on campus. The dual bins system we recommend is an appropriate method to solve this problem in that it can increase the recycling rate and decrease the waste going into the landfill. Compared with more advanced sorting machines or separate recycling bins for bottles, paper, glass and metals, the dual bins system has the advantages of low investment, convenient use and easy integration with the original system. The objective of this project is to determine the locations and the total number of dual bins required on campus and to conduct some environmental and economic evaluations to determine the feasibility of this system.

In the process of determining locations, in which we used questionnaire investigations, model analysis and a field trip, the total numbers of dual bins required outside the buildings on campus was verified to be 161. We found two-thirds of the dual bins will need extra concrete base which should be paved before installing the dual bins; two-thirds of them are at a crossing, which is easier for pedestrians to notice; and one-fifth are near a bus station, so further discussion with MTD company is necessary. To reduce huge investment at once, a pilot run was recommended with ten best locations we believed.

This system was also proved to have a positive and profound impact on the environment. The environmental assessment considers from two aspects: one is the decline of garbage entering landfills; the other is the increase of the recycling rate. Based on the pilot run on main quad and our calculations, the recycling rate can rise from almost zero to 24.5% with dual bins system. According to the recycling rate and the waste density in landfill, we figured out that more than 32 tons of recyclable materials will be reused and $269m^3$ land space which is approximately the size of 58,164 footballs will be saved if the dual bins system can be installed on campus.

The dual bins system has been verified to be economically feasible. According to the data about installation cost of the dual bin systems and the pilot run experiments, the total investment of this system is estimated at $624,341.19, and the annual revenue is estimated to be $27,568.46. In this way, the payback period is found to be 23 years. Meanwhile. The average service life period of the dual bins is about 25 years. The comparison between the payback period and dual bins service life shows the economic feasibility of the bins systems.

Based on the cost-benefit estimation and environmental impact assessment, it seems that the dual bins system is doable and environmentally friendly. We hope that with the improvement of students' sorting awareness, the recycling rate will be larger than the pilot run results because18.5% recyclables still cannot be reused with the usage of dual bins system.

Acknowledge

We would like to thank Mrs. Morgan White for assisting us to complete the project. She not only provided lots of useful information and resources but also shared some practical experience with us. She really gave us significant assistance. Furthermore, she found someone in some special areas to help us find good data, including Marya Ryan and Dennis Skultety. Marya Ryan provided different universities' diversion rates and Dennis Skultety showed us the pipe distribution on campus. Although we did not use all data they provided, we still would like to thank them. At the beginning, when our project concept is not concrete, professor Jeffrey Roesler gave us some critical questions which pushed us to think further. Professor Lance Schideman and Mrs. Morgan White took us to the sorting factory to get the picture how the University operates the garbage system. Professor Arthur Schmidt not only gave good and thoroughly feedback on our milestones but also gave us some good advice and encouragements. Professor Ken Paige who was very interesting in our project shared his experience and thoughts with us. Professor Mary Hays answered our grammar problems and helped us improve our writing. TAs in CEE 398 gave us some support and good advice. Thank our families, friends and people who were mentioned above to support us to finish the project.

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Group Reflection

Because English was the second language for both of us, we struggled to writing the project. Although we knew what we wanted to express, we always had trouble to make the thoughts into words. And what made the situation worse is that we wrote very long sentences with complicated structures. These situations turned out that our milestone 1 was very hard to read and even both of us did not very understand the other person's writing. Eventually, professors suggested us to attend the writing workshop or ask a writing coach for help. At that time, when we got the feedback of milestone 1, we suddenly realized that we had trouble in writing and started to figure out how to solve the problem. Therefore, we decided to finish our first draft of the milestone 2 two weeks earlier than the deadline. After finishing the first draft, we reviewed each other's writing very thoroughly and had comments beside the writing. It was a very frustrated time. Although both of us spent a lot of time and effort to make our writing readable and explained all the terms thoroughly, both of us had a lot of comments for each other. Despite comments were not harsh, it is very depressing to know that we still had a great room to improve. After revising all comments, we finished our second draft. And then we went to the writing workshop to ask some grammar questions. Although our writing was not in the same level with other classmates, we knew we had significantly improved our writing.

Appendix

Appendix A: The number of students in each department

Site	Latitude	Longitude	Student population
1205 ½ West Nevada Street	40.10573	-88.22464	20
1205 West Oregon Street	40.10668	-88.22482	16
1207 West Oregon Street	40.10639	-88.22477	3
Afro-Amer Studies & Rsch Prog	40.1057	-88.2241	24
Ag Engineering Sci Bldg	40.10168	-88.22636	265
Altgeld Hall	40.1093	-88.22838	1459
Animal Sciences Lab	40.10384	-88.22513	626
Architecture Bldg	40.10323	-88.22906	146
Armory	40.10475	-88.23195	399
Art & Design Bldg	40.10183	-88.23249	628
Astronomy Bldg	40.11094	-88.22093	158
Bevier Hall	40.10505	-88.22427	166
Burrill Hall	40.10917	-88.22481	1061
Chemical & Life Sci Lab	40.10811	-88.22432	80
Coble Hal	40.10873	-88.22923	60
College of Business Instructional Facility	40.10382	-88.2309	3135
Dance Studio	40.10558	-88.22015	68
Davenport Hall	40.10717	-88.22611	783
David Kinley Hal	40.10365	-88.22835	2006
Digital Computer Lab	40.11314	-88.22645	383
Education Bldg	40.10207	-88.22962	1612
Electrical and Computer Engineering Bldg	40.11492	-88.22802	2754
Engineering Hall	40.11077	-88.22695	278
English Bldg	40.10753	-88.22824	540
Foreign Languages Bldg	40.10625	-88.22607	607
Freer Hall	40.10488	-88.22291	1310
Gregory Hall	40.1056	-88.22808	3876
Huff Hall	40.10358	-88.23274	694
Illini Hall	40.10944	-88.22925	820

Illini Union Bookstore	40.10833	-88.22912	2994
Institute for Genomic Biology	40.10477	-88.2247	278
International Studies Bldg	40.10721	-88.23162	15
Krannert Ctr for Performing Arts	40.10799	-88.22274	201
Labor & Employment Relations, School o	40.10564	-88.23156	251
Law Bldg	40.10094	-88.23196	487
Library & Information Science	40.10767	-88.2315	809
Lincoln Hall	40.10661	-88.22819	1914
Loomis Lab	40.11091	-88.22335	565
Mechanical Engineering Bldg	40.1112	-88.22508	1437
Morrill Hall	40.10875	-88.22443	117
MUMFORD HALL	40.10361	-88.22602	1717
Music Bldg	40.10639	-88.22319	670
Natural History Bldg	40.10936	-88.22586	353
Newmark Lab	40.11396	-88.22656	1324
Noyes Lab	40.10841	-88.22606	843
Psychology Bldg	40.10748	-88.22995	1688
Roger Adams Lab	40.1076	-88.22416	1698
School of Social Work (Gregory Place II)	40.10643	-88.22106	607
Siebel Ctr for Computer Sci	40.1138	-88.2249	2324
Speech & Hearing Clinic	40.10762	-88.23072	324
Swanlund Admin Bldg	40.10883	-88.23003	3
Talbot Lab	40.11185	-88.22824	904
Temple Hoyne Buell Hall	40.10215	-88.22783	766
Transportation Bldg	40.11166	-88.22519	638
Turner Hall	40.10284	-88.22421	608
Vet Med Basic Sciences Bldg	40.09176	-88.21908	627
Wohlers Hall	40.1036	-88.22984	3078

Appendix B: The number of students in each dormitory

Site	Latitude	Longitude	Student population
Allen hall	40.10434	-88.220861	651
Busey	40.105862	-88.222416	193
Evans	40.105894	-88.223201	196
Townsend	40.1099	-88.221333	627
Wardall	40.10976	-88.221735	548
Lincoln Avenue Residence Halls (LAR)	40.104352	-88.220406	488
Oglesby	40.099347	-88.221276	622
Trelease	40.099127	-88.220395	619
Babcock	40.100028	-88.221005	254
Carr	40.100829	-88.220358	256
Blaisdell	40.100578	-88.219801	254
Saunders	40.099894	-88.219757	254
Barton	40.103491	-88.234065	132
Lundgren	40.104172	-88.23403	132
Hopkins	40.102698	-88.237812	440
Nugent	40.104157	-88.237264	461
Wassaja	40.104061	-88.238077	491
Weston	40.101666	-88.236503	455
Bousfield	40.102275	-88.238171	472
Scott	40.102258	-88.236694	444
Snyder	40.102251	-88.235105	454
Van Doren	40.115327	-88.233833	200

Appendix C: The detailed information for each location

Site ID	Concrete	Crossing	Bus Stop	Latitude	Longitude
1	0	1	0	40.11448	-88.2276
2	0	1	0	40.11527	-88.22768
3	0	1	0	40.11527	-88.22705
4	0	1	0	40.11449	-88.22703
5	0	1	0	40.11455	-88.22577
6	0	1	0	40.11539	-88.22576
7	1	1	1	40.11552	-88.22415
8	1	1	0	40.11459	-88.22411
9	0	1	0	40.1136	-88.22411
10	1	0	0	40.11363	-88.22546
11	0	1	0	40.11356	-88.22725
12	1	0	0	40.11284	-88.22723
13	1	1	0	40.11267	-88.22551
14	0	1	0	40.11264	-88.22409
15	1	1	0	40.11284	-88.22382
16	0	1	0	40.11283	-88.22245
17	1	0	0	40.11261	-88.22781
18	1	1	0	40.11219	-88.22567
19	1	0	0	40.11148	-88.22649
20	0	0	0	40.11190	-88.22770
21	1	1	0	40.11151	-88.2288
22	0	0	0	40.11142	-88.22768
23	1	0	1	40.11167	-88.22408
24	1	1	0	40.11143	-88.22544
25	0	0	0	40.11109	-88.22774
26	0	1	0	40.11113	-88.22648
27	1	0	0	40.11061	-88.22771
28	1	1	0	40.11045	-88.2287
29	0	0	0	40.10998	-88.22733
30	1	1	0	40.11059	-88.22648
31	1	0	1	40.11165	-88.2238
32	1	1	0	40.11137	-88.22409
33	1	1	0	40.11060	-88.22542
34	1	1	0	40.11145	-88.22550
35	1	1	0	40.11061	-88.22408
36	1	0	0	40.11227	-88.22253
37	1	0	0	40.11229	-88.22164

38	0	0	0	40.11128	-88.22247
39	0	1	0	40.11064	-88.22113
40	0	1	0	40.11066	-88.22201
41	1	0	0	40.11109	-88.22066
42	1	1	0	40.10897	-88.23026
43	1	1	0	40.10919	-88.22903
44	1	0	1	40.10818	-88.22895
45	1	1	0	40.10865	-88.23025
46	1	1	0	40.10789	-88.23102
47	1	1	0	40.10787	-88.23188
48	1	0	0	40.10726	-88.23215
49	0	1	0	40.10727	-88.23019
50	1	1	0	40.10689	-88.23136
51	1	0	0	40.10619	-88.23015
52	0	0	0	40.10584	-88.23209
53	1	1	0	40.10531	-88.23046
54	1	1	0	40.10551	-88.23217
55	1	1	0	40.10551	-88.23323
56	1	0	0	40.10533	-88.22894
57	0	0	0	40.10458	-88.23044
58	1	1	1	40.10422	-88.23042
59	1	0	0	40.10427	-88.23117
60	0	1	0	40.10424	-88.23332
61	1	1	0	40.10407	-88.23012
62	0	0	0	40.10317	-88.23233
63	0	1	0	40.10316	-88.23038
64	0	0	0	40.10309	-88.22947
65	0	1	0	40.10262	-88.23009
66	1	0	0	40.10234	-88.22847
67	1	0	0	40.10234	-88.22847
68	0	0	0	40.10208	-88.23321
69	1	0	0	40.10135	-88.23132
70	1	0	1	40.10180	-88.23005
71	1	0	0	40.10166	-88.23008
72	0	0	0	40.10142	-88.22960
73	0	0	0	40.10142	-88.22852
74	1	0	0	40.10160	-88.22817
75	1	1	1	40.11015	-88.22854
76	1	1	1	40.11020	-88.22802
77	1	1	0	40.10933	-88.22792

78	0	1	0	40.10884	-88.22782
79	1	1	1	40.10879	-88.22874
80	1	1	0	40.1087	-88.22755
81	0	1	0	40.10808	-88.22761
82	1	1	0	40.10876	-88.22689
83	1	1	0	40.10806	-88.22686
84	0	1	0	40.10874	-88.22568
85	1	1	0	40.10807	-88.22566
86	1	1	1	40.10791	-88.22404
87	1	1	0	40.10907	-88.22406
88	0	0	0	40.11001	-88.22569
89	1	0	0	40.10982	-88.22648
90	1	1	0	40.10791	-88.22678
91	1	1	0	40.10794	-88.22752
92	1	1	0	40.10735	-88.22754
93	1	0	0	40.10722	-88.2268
94	1	1	0	40.10636	-88.22756
95	1	1	0	40.10643	-88.22681
96	1	1	0	40.10568	-88.22737
97	1	1	0	40.10535	-88.22682
98	1	1	0	40.10802	-88.22541
99	1	1	0	40.10703	-88.22539
100	0	1	0	40.10646	-88.22566
101	1	1	0	40.10604	-88.22562
102	1	1	1	40.10703	-88.22400
103	1	1	1	40.10606	-88.22396
104	1	0	0	40.10499	-88.22732
105	1	0	0	40.10500	-88.22703
106	1	1	1	40.10423	-88.22821
107	0	1	1	40.10425	-88.22662
108	1	1	0	40.10306	-88.22802
109	1	1	0	40.10532	-88.22551
110	1	1	0	40.10411	-88.22581
111	1	1	1	40.10486	-88.22390
112	1	1	1	40.10459	-88.22388
113	0	0	1	40.10407	-88.22469
114	1	1	0	40.10336	-88.22489
115	1	1	0	40.10326	-88.22562
116	1	1	0	40.10302	-88.22647
117	1	1	0	40.10248	-88.22669

118	1	1	0	40.10243	-88.22561
119	1	0	0	40.10257	-88.22338
120	1	1	0	40.10221	-88.22460
121	1	1	0	40.10144	-88.22660
122	1	1	0	40.10139	-88.22550
123	1	1	0	40.10141	-88.22432
124	1	1	1	40.10071	-88.22435
125	1	0	1	40.11040	-88.22150
126	0	1	1	40.10890	-88.22372
127	0	0	1	40.10914	-88.22065
128	1	0	1	40.10912	-88.22213
129	1	0	1	40.10830	-88.22372
130	0	0	0	40.10824	-88.22170
131	1	1	0	40.10855	-88.22005
132	0	1	0	40.10711	-88.22369
133	0	1	0	40.10710	-88.22168
134	0	1	1	40.10712	-88.21937
135	0	0	0	40.10690	-88.22051
136	0	0	0	40.10647	-88.21935
137	0	0	0	40.10606	-88.22076
138	1	1	1	40.10605	-88.2237
139	0	0	1	40.10587	-88.22232
140	1	1	1	40.10588	-88.22140
141	1	1	0	40.10547	-88.22298
142	0	1	0	40.10539	-88.22141
143	1	1	0	40.10543	-88.22234
144	0	1	1	40.10607	-88.21939
145	0	1	0	40.10489	-88.22079
146	1	0	1	40.10451	-88.22373
147	1	0	0	40.10458	-88.21931
148	0	1	0	40.10341	-88.22298
149	0	1	0	40.10342	-88.22196
150	1	1	1	40.10427	-88.22207
151	0	0	1	40.10230	-88.22192
152	1	1	0	40.10330	-88.22104
153	0	1	0	40.10305	-88.21929
154	0	1	0	40.10240	-88.21926
155	0	1	1	40.10071	-88.22014
156	1	0	1	40.10411	-88.21932
157	0	1	0	40.10133	-88.22190

158	1	1	1	40.10073	-88.22192
159	0	1	0	40.10137	-88.22358
160	1	1	0	40.11224	-88.22382
161	0	1	0	40.10157	-88.22362

Appendix D: The bins' weight at 27 locations

(Data is from "Quad Recycling Containers Implementation Project")

Location ID	Landfill Bin (lb)	Recycling Bin (lb)	Bottles and Cans		Recycled in the community		Trash	
			Unit: lb	Unit: kg	Unit: lb	Unit: kg	Unit: lb	Unit: kg
1	5.60	1.80	0.94	0.42	0.40	0.18	6.07	2.75
2	8.10	1.50	0.78	0.35	0.33	0.15	8.49	3.85
3	8.70	1.20	0.62	0.28	0.26	0.12	9.01	4.09
4	10.50	3.00	1.56	0.71	0.66	0.30	11.28	5.12
5	4.50	2.10	1.09	0.50	0.46	0.21	5.05	2.29
6	7.30	8.30	4.32	1.96	1.83	0.83	9.46	4.29
7	5.80	3.30	1.72	0.78	0.73	0.33	6.66	3.02
8	4.30	1.35	0.70	0.32	0.30	0.13	4.65	2.11
9	7.10	1.70	0.88	0.40	0.37	0.17	7.54	3.42
10	5.90	3.20	1.66	0.75	0.70	0.32	6.73	3.05
11	3.10	1.40	0.73	0.33	0.31	0.14	3.46	1.57
12	4.40	1.90	0.99	0.45	0.42	0.19	4.89	2.22
13	2.70	1.80	0.94	0.42	0.40	0.18	3.17	1.44
14	5.00	1.50	0.78	0.35	0.33	0.15	5.39	2.44
15	2.30	1.70	0.88	0.40	0.37	0.17	2.74	1.24
16	1.50	1.60	0.83	0.38	0.35	0.16	1.92	0.87
17	1.50	3.40	1.77	0.80	0.75	0.34	2.38	1.08
18	1.50	1.80	0.94	0.42	0.40	0.18	1.97	0.89
19	2.00	1.40	0.73	0.33	0.31	0.14	2.36	1.07
20	1.60	0.80	0.42	0.19	0.18	0.08	1.81	0.82
21	2.10	2.10	1.09	0.50	0.46	0.21	2.65	1.20
22	1.90	1.50	0.78	0.35	0.33	0.15	2.29	1.04
23	3.50	1.30	0.68	0.31	0.29	0.13	3.84	1.74
24	3.10	2.00	1.04	0.47	0.44	0.20	3.62	1.64
25	1.30	0.30	0.16	0.07	0.07	0.03	1.38	0.63

26	1.00	0.85	0.44	0.20	0.19	0.08	1.22	0.55
27	1.60	0.70	0.36	0.17	0.15	0.07	1.78	0.81
Total	107.90	53.50	27.82	12.62	11.77	5.34	121.81	55.25
Average	4.00	1.98	1.03	0.47	0.44	0.20	4.51	2.05