Region of Peel
Working for you

Onboard Weigh Scales

A Multi-Family Weight-Based Waste and Recycling Generation Pilot

Stewardship ONTARIO

Effectiveness and Efficiency Fund Project #123

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Prepared by: Peter Kalogerakos

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The Regional Municipality of Peel 10 Peel Centre Drive, Suite A Brampton, ON L6T 4B9
Tel: (905) 905-791-7800 • Fax: (905) 791-2398 • www.peelregion.ca

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- Creative Microsystems Inc.
- Silver Top Supply Ltd.
- Waste Management Corporation of Canada

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Executive Summary

The Region of Peel provides waste collection services to over 650 multi-family properties including 88,000 multi-family units. Diversion rates remain very low averaging around 13 to 14 per cent, which is not an uncommon figure in the multi-family sector across the province. As part of the Region's efforts to increase diversion in this sector, a pilot project was initiated through Stewardship Ontario's Effectiveness and Efficiency (E&E) Fund to test the use of onboard weigh scales to measure waste generation on a per building basis.

The purpose of the pilot project was to demonstrate the ability of onboard weigh scales to track the number and weight of individual lifts, generation rates (garbage and recycling) and diversion rates on a per building basis. Also, the scales were to be used to determine average waste densities for both garbage and recycling streams.

Onboard weigh scales have been piloted before in various municipalities in the US, Canada and abroad. The main focus in many of these pilots was to use the weights for a billing and/or tracking system often referred to as "Garbage by the pound". These pilots date back to the early nineties. Since then, onboard scale technology has no doubt improved, however there are few systems that are certified and approved for trade in the US and Canada. Due to the Canadian *Weight and Measures Act*, weights cannot be used for billing purposes, unless approved by the Minister of Industry (Section 3 of the Act). However, with improvements in accuracy, measured weights may provide a method to track waste generation while onboard scale activity can track the number of lifts and stops.

Loadman® onboard weigh scales were used for this pilot as they were preferred by the Region's waste collection contractor Waste Management Corporation of Canada (WMCC). For the purposes of this pilot project, two front-loading garbage trucks were equipped with the front fork-mounted scales and two top-loading recycling trucks were equipped with body-mounted scales. Creative Microsystems Inc. has developed an integrated software package to allow the retrieval and manipulation of weight data which is transmitted via an internet connection to a user's desktop.

Project constraints and limitations included: 1) the design of the data flow network between the Region, Creative Microsystems Inc. and WMCC and 2) the use of bar-coded route sheets to record the lifts and generate the data. The complexity of the system design to allow data communication between the trucks and a user's desktop presented some unforeseen delays. In addition, the use of bar codes to identify a stop and/or container type required the drivers to scan a bar-coded route sheet, introducing a manual process, which not only adds an extra step for the drivers but introduces the possibility of an error in the process. A possible next step in the use of the onboard weigh scale technology would be to test the integration of Radio Frequency Identification (RFID) technology with the onboard weigh scales. This would eliminate the need for a manual data capture process and provide an automated method to capture stop and bin information.

Overall, both onboard weigh scale systems were successful in capturing waste generation data on a per building basis. Using the data captured, diversion rates were calculated per building as well as waste densities for various types and sizes of garbage and recycling containers. The average generation rates calculated for garbage (12.2 kg/unit/week) and recycling streams (1.7 kg/unit/week) closely match the rates found in previous waste audits. The calculated average diversion rate (14%) also closely matches what was found in previous waste audits and tonnage reports. Density estimates based on the results of this study are as follows: compacted garbage 115 kg/yd^3; un-compacted garbage 65 kg/yd^3; single stream cart-based recycling 40 kg/yd^3 and single stream front-end recycling 38 kg/yd^3 . The accuracy of both onboard weigh scale systems was found to be acceptable for tracking purposes, with the front-fork mounted weigh scale system being off by an average of 4 kilograms per lift and the body-mounted weigh scale system being off by an average of 7 kilograms per stop or 1 kilogram per cart. There is great potential in the technology tested in this pilot, as the data can be used for multiple purposes to help increase diversion in this often hard to reach sector.

1.0 Background

1.1 Waste Management in Peel Region

The Region of Peel provides waste collection services for approximately 300,000 single-family households and 88,000 multi-family units. The following streams are included in the waste collection services provided to over 650 multi-family properties in the Region: garbage, single-stream recycling, white goods and bulky items. Front-end bins are generally used for garbage disposal and 95 gallon (360 litre) carts are used for recycling. The Region will be introducing front-end recycling collection (utilizing 3, 4 and 6 cubic yard bins) to suitable properties over the next few years. It is estimated that approximately 50 per cent of multi-family properties in Peel Region can ultimately be converted from cart-based collection to front-end collection for recycling.

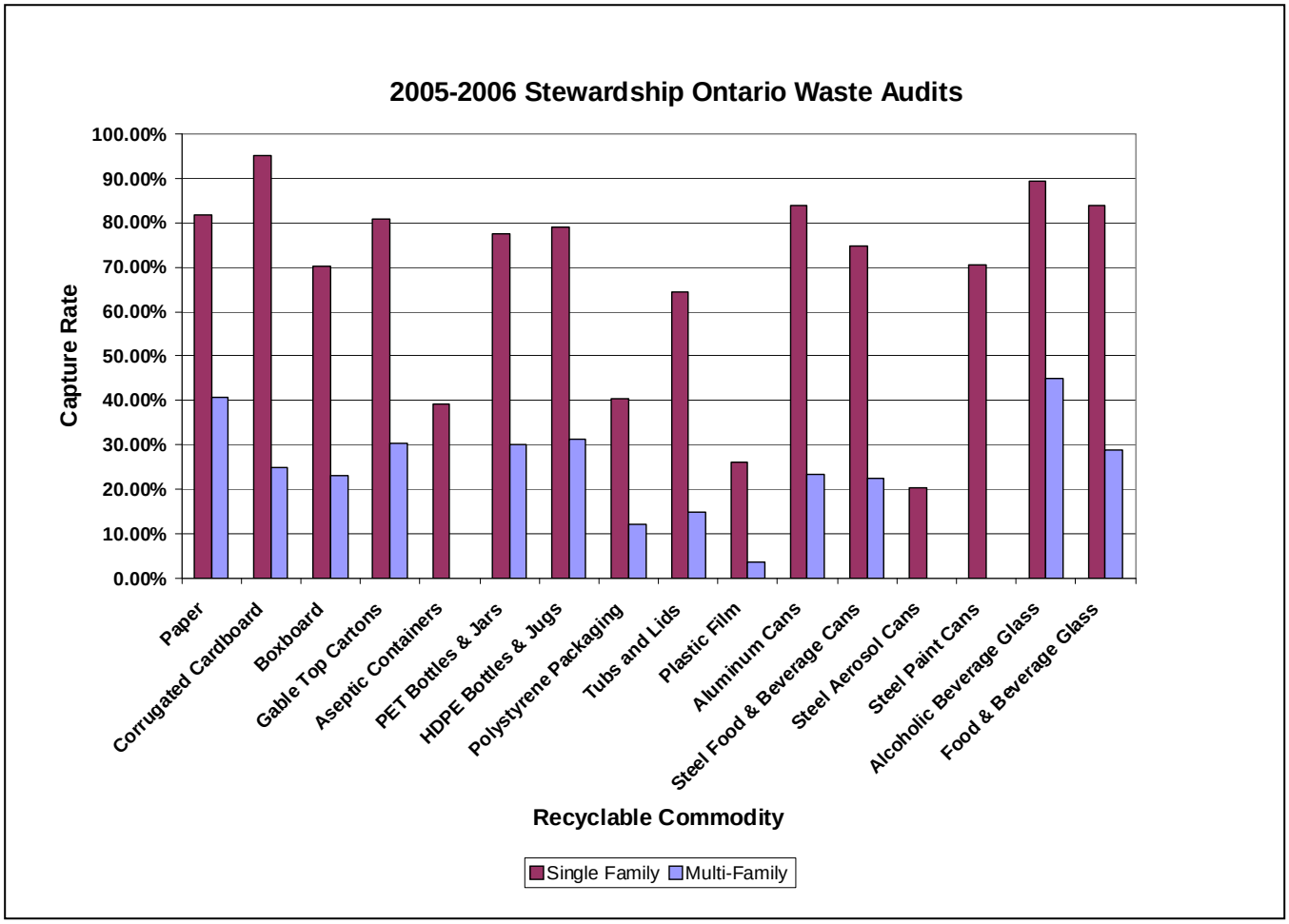
Based on the results from the 2005/2006 Stewardship Ontario-funded Multi-Family Waste Audit Program, the average diversion rate achieved by multi-residential households in Peel was 13 per cent. This is significantly lower than the diversion rate achieved through recycling in single family households in Peel (approximately 33 per cent). Figure 1 illustrates the disparity between single-family and multi-family capture of recyclables. The average capture rate of recyclables was found to be 80 per cent for single-family households and 32 per cent for multi-family households. This disparity between multi-family and single family diversion rates can be attributed to the fact that multi-family households are, for the most part, subjected to barriers to recycling. These barriers may include the fact that:

a) recycling is not as convenient as garbage disposal;
b) the capacity for a recycling area in the building may be limited;
c) building owners/superintendents may not be diligent in promoting recycling to tenants; and/or
d) there is a lack of recycling knowledge due to various factors such as high tenant turnover rates and minimal connection to the recycling program.

In an effort to improve the capture of recyclables and increase participation in the recycling program by multi-family households, the Region of Peel is undertaking various initiatives and implementing service enhancements. Major initiatives include:

1) Inventory of multi-family properties and creation of multi-family property database.
2) Promotion and education (P&E) Improvements e.g. lobby displays, new laminated sorting posters, recycling handbook for owners, property managers and superintendents, annual multi-family waste management guide.
3) The implementation of front-end recycling collection to allow for additional capacity at multi-family properties thereby increasing storage and collection efficiency.
4) A pilot project to test onboard weigh scales. The onboard weigh scales will provide data on the weight of garbage and recyclables, for select multi-family properties.

Figure 1 - Single Family vs Multi - Family Recycling Capture Rates



1.2 Project Overview

Under Project #123 of Stewardship Ontario's Effectiveness and Efficiency (E&E) Fund, the Region of Peel obtained funding to pilot the use of onboard weigh scales for two (2) front-end garbage trucks and two (2) top-loading recycling trucks. The scales were used to measure and record the weight of waste and recycling generation on a per building basis. The onboard weigh scales will provide data on the amount of recyclable material and garbage generated by specific buildings.

This pilot project demonstrates the potential of onboard weigh scale systems to:

- track the number and capacity of lifts (garbage and recycling) per building
- calculate an overall diversion rate per building (the scales will provide the weight of garbage and recycling in kg/building/week. From this measurement, a generation rate (kg/unit/week) can be calculated);

- determine the density of recyclable materials, particularly in a cart-based single stream recycling system. This information will be useful to other municipalities who wish to obtain the average density of single stream recyclables;
- determine the density of garbage in various bin sizes which are compacted and un-compacted. The average density of garbage can be used in calculating waste volume limits. The scales will provide accurate waste density information which is collected within the Region.

Benefits to tracking this type of data include:

- the ability to evaluate which buildings are meeting or exceeding the current bag standard (two bags per week for all households) for waste collection. The scale data will allow the Region's Waste Management Division to evaluate the applicability of a volume based user pay system;
- the potential to identify and assist buildings with low recovery of recyclables, through education and outreach efforts, on-site assessments, enforcement tools, etc;
- measure the impact on the recovery of recyclables after the introduction of front-end recycling collection (generation rates were calculated for each building before and after a building's recycling carts were replaced with front-end bins for collection).

2.0 Onboard Weigh Scale Systems

2.1 Introduction

Onboard weigh scales are used more frequently by private sector waste collectors to monitor truck loads and maximize their pay loads. Onboard weigh scales have become more accurate, reliable and user-friendly over the years. Some onboard weigh scale providers offer software suites that allow tracking of weights by customer and offer GPS capabilities to track collection fleets.

2.2 Certification of Onboard Weigh Scale Systems

The use of onboard weigh scales for commercial trade purposes is regulated by the federal government in Canada, under the *Weights and Measures Act* and *Regulations*. The *Weights and Measures Act* requires that:

- measuring devices be approved for use in Canada;
- only approved and certified measuring devices be used in measurement based transactions;
- owners and operators ensure their measuring devices measure accurately and are not used in a fraudulent manner;
- the quantities declared for products bought and sold on the basis of measurement be accurate within prescribed limits; and

- only units of measurement described in the Act be used in commercial transactions.

Owners and operators are legally responsible for ensuring their measuring devices measure accurately. In order to meet this requirement, owners and operators should make sure that their measuring devices:

- are approved and certified for use in Canada;
- are appropriate for their intended use. There are scales and meters designed with different features and capabilities to measure certain types of products, such as precious metal scales for measuring gold, vehicle scales for weighing trucks and trains, and onboard weigh scales to weigh various materials being lifted by the vehicle or added to its total load;
- are properly installed and protected from environmental interference;
- are used in a manner that ensures accurate measurement; and
- clearly indicate the amount of product weighed or measured.

In the United States (US), the use of onboard weigh scales for commercial trade purposes is regulated under the National Conference on Weights and Measures' "National Type Evaluation Program". The program issues a "Certificate of Conformance for Weighing and Measuring Devices" to successful applicants. Both Canada and the US operate federal certification and approval programs for weighing instruments intended for use in commercial applications. Manufacturers who wish to market their products in either country must, under the current rules and regulations, have them evaluated and approved in each country separately. However, Canada and the US have reached a bilateral agreement whereby one country recognizes the examination and tests of certain instrument types performed by the other country. This agreement is known as the Canada-US Mutual Recognition of Type Evaluation Program.

There are currently very few onboard weigh scales systems that are certified in Canada or the US for measuring the weight of residential waste. Many onboard weigh scale systems are installed and certified on lift trucks or front-end loaders. And there are examples in the US and Canada of certified onboard weigh scales systems using front-end fork mounted weigh-in-motion technology similar to the one piloted in this study. However, there are also manufacturers that have not yet obtained certification by either federal body.

2.3 Case Studies – North American and International Experience

Research from Skumatz Economic Research Associates Inc. in the US indicates that numerous communities in the US and Europe have pilot tested onboard weigh scale systems in what is referred to as "Garbage by the Pound" (GBTP) systems. In North America, there was much activity in testing GBTP systems in the early to mid 1990s spanning almost two dozen communities in the US and Canada. Onboard weigh scale systems began certification in the US in 1994 and 1995. Although, many programs have been implemented in Europe, there currently is no long term citywide weight-based system using onboard weigh scales for residential collection in the US or Canada.

2.3.1 Seattle, Washington

One of the first pilots related to Garbage by the Pound using onboard weigh scale systems was conducted by Seattle in 1989-90. It was a two-phase pilot using two different systems: 1) manual system using bar codes to generate data for mock bills and solicit feedback and 2) semi-automated tipper scale using radio-frequency identification (RFID) tags, used to identify carts and weights. RFID technology involves the use of a tag that is affixed to a product or object for the purposes of identification or tracking using radio waves. A reader is used to collect the information from the tag and the tags may be read from various distances. In the waste industry, readers are usually affixed to the waste collection vehicles. A handheld computer was used to download weights and a mock bill was sent to customers throughout the pilot. Project results suggested that customers reduced weights of their garbage set outs by 15 per cent and were supportive of the weighing system concept. The City's waste management services are currently a part of the public utilities service which operates a volume-based user pay rate structure.

2.3.2 Farmington, Minnesota

In 1991, the City of Farmington began testing onboard weigh scales to work towards implementing a weight-based rate structure for garbage collection. Due to technological setbacks and unsuccessful redesigns, the City abandoned work on the project. The City tested both RFID and bar-code based systems but ultimately experienced staff training issues and opposition from collection personnel.

2.3.3 RecycleBank, United States

RecycleBank is an organization based out of the US that has introduced an incentives-based recycling collection program. RecycleBank partners with local municipalities and/or waste haulers to provide rewards to residents for recycling. The RecycleBank system uses recycling carts outfitted with an RFID tag. The tag contains information on the household where the cart is located. The collection vehicle is equipped with an onboard scale located on a cart tipper. As the cart is tipped into the truck the RFID tag on the cart is scanned to identify the cart and the cart is also weighed at the same time. The more a household recycles, i.e. the heavier their cart is, the more RecycleBank points they receive. RecycleBank users each have an account that they can access and track their points and waste diversion numbers. Households can redeem their RecycleBank points at many local retail stores who have partnered with RecycleBank. This system is an interesting application for onboard scales, in that, the weights measured are not used for billing, but to reward households for participating in their recycling program. The RecycleBank program has been introduced to various communities in the U.S. such as: Cherry Hill, NJ, Philadelphia, PA and Hartford, CT.

2.3.4 Victoria, Capital Regional District (CRD), British Columbia

The CRD municipality of Oak Bay conducted a comprehensive pilot to weigh multiple streams of residential waste in the early 1990's. Collection staff piloted prototype equipment to simultaneously weigh and collect three waste streams (garbage, recycling, organics) using a triple packer truck. The truck was equipped with three tipping arms modified with load cell weighing technology and RFID technology. Participating residents received special carts with RFID tags. The system recorded the weight of material, type of material and generator address. The weight information was then downloaded remotely through a radio system to a computer at the municipal office. The pilot was offered to all citizens on a volunteer basis and 65% of residents participated. The pilot cost a total of $325,000 CDN, including $100,000 CDN for the specialized collection truck. The pilot was not implemented on a full scale basis because the onboard weigh scales did not meet Canada Weights and Measures requirements and the multi-compartment packer trucks used did not provide sufficient performance. The municipality of Oak Bay is currently collecting waste using the semi-automated collection method.

2.3.5 Sault Ste. Marie, Ontario

The City of Sault Ste. Marie installed a front fork-mounted onboard scale system in 2004. During the first six to eight months, weights measured by the onboard scale and the City's land scale did not match. Scale reliability has been an ongoing issue, but has improved as repairs and regular calibration have made corrections to the system. Currently, weights are only being used to track extra lifts carried out by the contractor.

2.3.6 Denmark

An unnamed community in Denmark used a fully automated cart system (approximately 90 gallon) to charge for garbage collection. Each cart contained the name and address of the resident and the weight was recorded by the electronic database in the truck. Residents were overall pleased with the system and it is reported that the weighing and recycling programs have cut the amount of garbage incinerated in half.

2.3.7 Australia

In 1994, an Australian city conducted a small pilot to weigh single-family residential waste. The system used RFID tags to record the stop address and associate it to the weight of the garbage can collected. This information was recorded at each stop as the garbage was emptied into the truck. Resident received statements or "mock bills" throughout the year with the quantity of their waste detailed, expected charges for that quantity and information on how they compared to other set outs in the community. The weighing technology used in the pilot was proven to be inaccurate. Therefore, due to these reasons, the weight-based system was not pursued further.

2.3.8 Adoption of full scale weight-based or garbage by the pound systems

Communities that have piloted the use of onboard weigh scales have cited several reasons why the systems they have tested were not implemented full scale. One main reason was that that the equipment was unreliable. The potential of the technology and will to use it was ahead of its certification. Most of the pilots undertaken used technology that was still in the testing stage. Certain pilots noted that weights were unreliable; in one pilot the scales read zero in the morning and were off by the afternoon. In other pilots, the incline in streets affected the weights on uncertified equipment that was tested. Although certified equipment is now available, the risk and costs associated with such equipment and systems appeared to be the major concerns.

While many of these case studies focused on onboard scale technology and its application for weight-based billing, there is another application: to use onboard scales for tracking waste generation on a per building basis and perhaps in tracking volume-based collection for billing purposes. Volumes can be tracked using the lift information from each stop that subsequently populates the Loadman® Fleet Manager Software. This was the focus of this pilot project.

3.0 Loadman® Onboard Scales

Loadman® onboard weigh scales were chosen for use in this pilot study upon request from the Region of Peel's waste collection contractor Waste Management Corporation of Canada (WMCC). WMMC currently uses Loadman® onboard weigh scales on a portion of their fleet in the Kingston, Ontario area and thus were confident that the scales would perform and be compatible with their existing fleet equipment. Loadman® onboard weigh scales have been developed by Creative Microsystems Inc. of Renton, WA in the United States. Creative Microsystems Inc. has over 18 years experience in designing and building onboard vehicle weighing systems. Silver Top Supply Ltd. (based in London, Ontario) are the Canadian distributers for Loadman® and provided installation and technical support services throughout the pilot project. Two different Loadman® onboard weigh scale systems were used in this pilot project: 1) front loader fork-mounted onboard weigh scales and 2) body-mounted onboard weigh scales, both of which will be described in the following sections.

3.1 Front Loader Fork-Mounted Onboard Scale System

The Loadman® fork-mounted system is a weigh-in-motion or dynamic weighing system as opposed to a static weighing system. Weigh-in-motion or dynamic weighing systems do not reduce driver productivity as weights are measured during the lift cycle and the lift does not need to be stopped while a measurement is taken. Onboard microcomputers take into consideration the fork angle, arm angle, velocity, and acceleration through the entire lifting cycle. Richard Boyovich of Creative Microsystems Inc. further explains this concept:

"For frontloaders, Loadman's proprietary microcomputer 'learns' the load-cell waveform as a function of the angle and position of the lift arm and the front forks relative to a tenth of a

degree throughout the entire lifting cycle. The system weighs the container in motion going up and then reweighs it in motion coming down, thus providing the net content of the container without stopping the front forks for the weight reading. The system completely ignores vibration and shock from running motors and measures the material regardless of where the weight is located in the container. Moreover, the system automatically compensates for out-of-level weighing conditions. As a result of these features, the system's weighing accuracy is typically within 1 %".

One limitation that affects this system is bin collection from docks. Bins that are located on loading docks are at an elevated height. The weigh-in-motion system requires that the bin begin its lifting cycle closer to ground level (i.e. around the area of a truck's headlights, as a guideline). Therefore, in order to accurately record the net weight of a bin located on an elevated loading dock, the bin must first be picked-up and placed on the ground before the lift cycle is completed.

In this system the load cells and microcomputer are located in the front-fork casing and are thus protected from, wear and tear from external shocks. Because of this, this system is deemed to be very stable and reliable, requiring minimal calibration.

3.2 Body-Mounted Onboard Scale System

The Loadman® body-mounted onboard scale system is a four-point under body system, with two load cells mounted at the rear and two load cells mounted at the front between the truck chassis and the superstructure. Loadman® has a patented load cell design called the "Axial Shear Beam" load cell. This design offers twice the signal output compared to other designs in the industry. All onboard load cells that are mounted between the truck chassis and superstructure experience significant stresses as the truck frame flexes. This can have detrimental effects on the accuracy of weight reading. Loadman's Axial Beam Load Cell minimizes the torsional stresses with a stronger, more twist resistant load cell. The two top-loading recycling trucks were equipped with this system, however only two of the four load cells were the Axial Beam design and the other two load cells had to be customized to fit the manufacturer's chassis (Walinga). These customized load cells were two-pin style 2.25 OD Radial Load Cells.

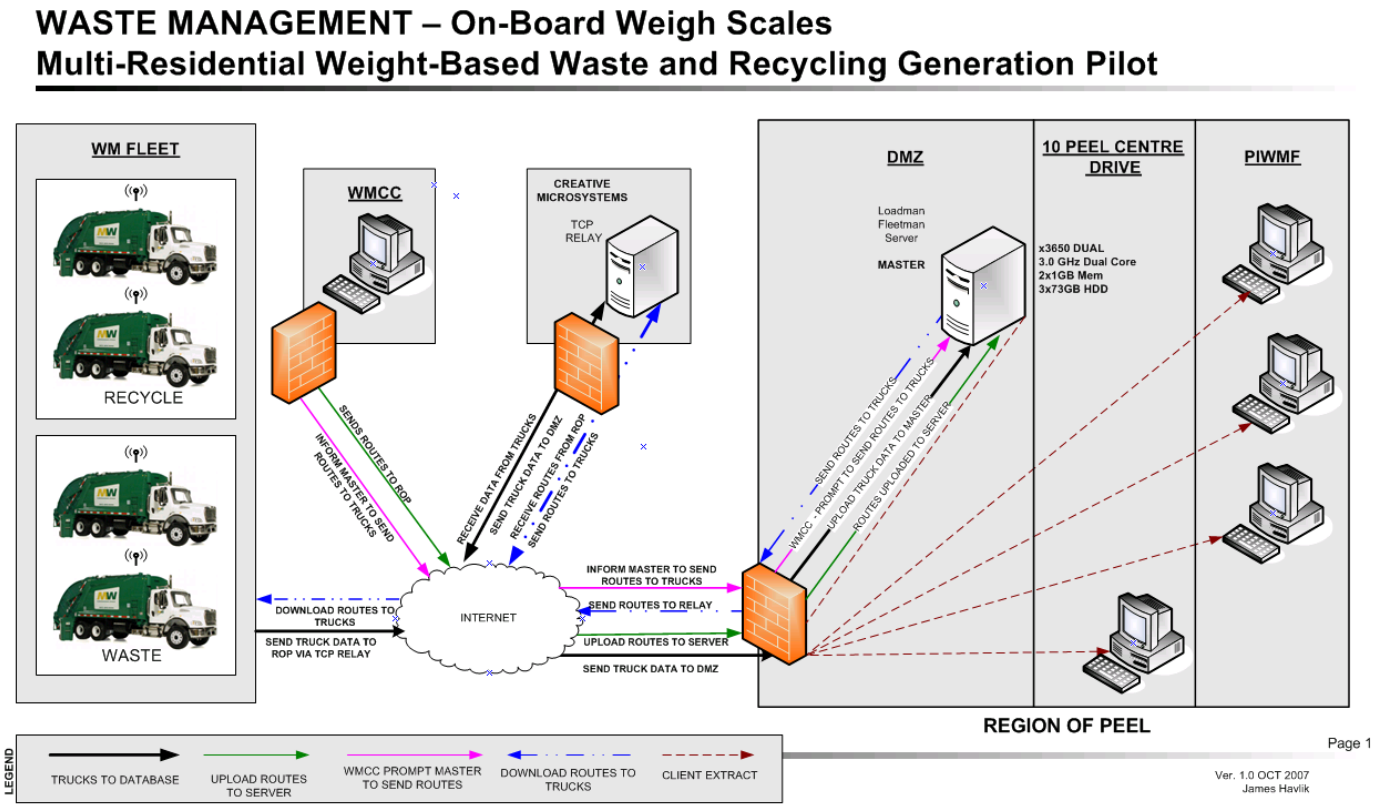
3.3 Collection of Data Using Loadman® Onboard Weigh Scales

3.3.1 Loadman® Fleet Manager Software

Creative Microsystems Inc. has developed a complete application package to accompany their onboard scale hardware. Their Fleet Manager Software offers remote downloading of the data collected by the collection vehicles equipped with the onboard weigh scales. The software package runs on Microsoft SQL (Structure Query Language) Server 2000 or an XP database located on a server to allow the use of staging tables for importing and exporting of collected data into other systems. Load data that is recorded may include, date and time of

collection and upload, vehicle ID, customer name or address, load weight, type of service, etc. The trucks are equipped with a wireless modem to communicate through a Transmission Control Protocol (TCP) relay system, where the data is relayed from Creative Microsystems' internet server to the server located at the Region of Peel. Satellite computers can then be set up for users who wish to view and manipulate the data collected by the trucks. Figure 2 below summarizes the data flow from the trucks to a user's desktop in the office.

Figure 2 - Transfer of Onboard Weigh Scale Data



Data is collected from each stop using a bar-coded route sheet. Existing routes are imported into the Fleet Manager Software and bar-coded route sheets can be generated and printed for the drivers use. A bar code wand is located in the cab and appropriate bar code(s) are scanned at each stop to record the required data.

The Fleet Manager Software also has Global Positioning System (GPS) capabilities. This application has added benefits, in that, trucks can be tracked throughout the route and using the "geofencing" feature particular addresses can be identified and recorded without driver intervention by the GPS unit. Although the Region of Peel has installed GPS receivers on all trucks equipped with scales, this capability has not been tested.

3.3.2 Front Loader Fork-Mounted Onboard Scale System

An office-type binder with bar-coded route sheets for each collection day is located in the truck for the driver(s) to use. Front loading trucks service a variety of types and sizes of front-end garbage bins; generally from 2 to 8 yd^3 which may be compacted or un-compacted. To account for this variety, the bar-coded route sheets contain the number, size and type of garbage bins at each stop or building. Each type and size of bin has a separate bar code. When the driver enters a multi-family property he locates the building on the route sheet then scans the bar-code corresponding to each particular bin he is lifting. Once scanned, the bin is then lifted and the weight is then recorded during the lift. The building address, bin size and type (service type) and weight is automatically sent to Creative Microsystems' remote server which, in turn, relays the data to the Region of Peel server where users can access the data on their desktops.

3.3.3 Body-Mounted Onboard Scale System

A binder with bar-coded route sheets for each collection day is located in the truck for the driver(s) to use. Top-loading trucks are used to service 95 gallon carts for the collection of single stream recyclables in the Region of Peel. Two smash boxes are located in the truck cab (one on the dash to the right of the driver, the second at the exterior right of the cab, for convenience). The smash box has a red button (zero) and a green button (record). When the driver enters a multi-family property he locates the building on the route sheet then scans the bar-code corresponding to the building address. Once the address is scanned it is registered in the scale meter. The driver then must zero the scale otherwise it weighs a cumulative weight of the payload . Once the scale is zeroed, the driver then proceeds to collect the materials from the carts set out for collection. Before the driver continues to the next stop he must press the green button (record) to record the total weight added to the truck.. This process must be repeated for each stop. Every time the green (record) button is pressed it is registered as a record and transmitted into the Fleet Manager Software.

Refer to the Appendix for photos of Loadman® Onboard Scale Components

3.3.4 Other Data Download Options

In locations where wireless communications are limited or non-existent, data can still be downloaded by connecting an onboard printer to the scale meter in the truck cab.

4.0 Methodology and Findings

4.1 Constraints and Limitations

This pilot project was subject to various constraints and limitations which have presented themselves throughout the project. The inherent complexity of piloting a technology such as onboard weigh scales coupled with the required participation of a waste collection contractor and onboard scale provider(s), has proved to be a challenging exercise. One difficulty encountered involved the mutual agreement to install the onboard scale system on the Region's waste collection contractor's vehicles. This required a significant legal and risk management exercise between the Region and WMCC which pushed the project timeline back.

Another constraint involved the coordination and approval of data communication between the Region, WMCC and Creative Microsystems Inc. Due to the fact that data flowed via the TCP relay system over the internet and access to the Region and WMCC servers was required, computer infrastructure and security was of paramount importance to the Region and WMCC. Therefore, both parties required time to obtain approvals and open up the necessary connections to allow the weight data to flow properly as designed by Creative Microsystems Inc. Again, this added to the project timeline. Should a municipality wish to implement a similar project or technology, these constraints should be considered. When using a waste collection contractor, significant work needs to be done up front to ensure all the necessary agreements are in place and the installations are not pending approvals and system design issues. A similar project may be less onerous or complex if a municipality provides waste collection service directly to residents, as there is more control over the collection fleet and computer network system, in general.

Another limitation involves the nature of data capture in this pilot project. As the onboard scale weigh system relies on bar-code scanning, the data capture is strictly reliant on the diligence of the truck operator. There is always the potential for error when a manual process such as bar-code scanning is employed.

The pilot project was also subject to unscheduled truck breakdowns which compromised the data collection for certain weeks as weight data was lost for certain days. Due to the twice weekly collection of garbage, if the data from one of the garbage collection days was missing, a weekly generation rate could not be calculated.

Finally, there were some limitations due to the fact that only two front-end garbage trucks and two top-loading recycling trucks were equipped with scales. As garbage is collected twice a week per building, this limited the building sample size as only those buildings that were collected by the trucks equipped with the onboard scales on both collection days could be used. In order to calculate a diversion rate, the buildings that were recorded twice a week by the scales for garbage generation had to be matched by the recycling trucks equipped with the scales. Also as mentioned previously, truck breakdowns resulted in some missing data. This would be less of an issue if the onboard scales were equipped on all waste collection

vehicles (including spares). Any breakdowns could then be mitigated by using another truck equipped with scales.

4.2 Scale Accuracy

Creative Microsystems Inc. claims that their Loadman® onboard scale systems provide an accuracy on average of less than .50 per cent error on gross payload. Further to this, their front fork weighing systems provide accuracy within 1 per cent. These specific claims have not been tested in this pilot project, however overall scale accuracy has been assessed. To determine the level of accuracy of both scale systems used in the pilot, the net weights measured by the Loadman® onboard weigh scales were compared to the net weights measured by the Region's land scale.

The front fork-mounted onboard weigh scale accuracy was determined by comparing net weights as previously described as well as taking the average net weight difference per route and dividing by the average number of lifts performed to get an average weight per lift that the scales were off by. On average, the front fork-mounted onboard weigh scale system was off by 4 kilograms per lift.

The body-mounted onboard weigh scale accuracy was determined by comparing the net weight difference and the number of stops and carts collected. On average, the body-mounted onboard weigh scales were off by 7 kilograms per stop or 1 kilogram per cart.

In general, the accuracy of both systems is deemed to be acceptable for tracking waste generation on a per building basis. Although weights cannot be used for billing purposes, they can be a good indicator of waste generation and diversion in the multi-residential sector. Calibration is recommended on an annual basis to ensure the scales are performing properly. Ad hoc accuracy tests (net weight comparisons) are also recommended to ensure continued accuracy throughout the year.

4.3 Data Manipulation and Analysis

Weight data transmitted by the onboard scales were managed using Loadman® Fleet Manager Software. The software application offers various options for data manipulation and reporting. The load data window closely resembles a Microsoft Excel spreadsheet, with columns and rows that can be organized to the user's preference. Filters can be created to load a particular set of weight data according to the preferences set by the user. For example, filters can be created to sort the data by truck number, date, building address, service type, etc. The software can also create customized reports, based on user preference. Data can also be exported into Microsoft Excel to allow for further data analysis. Refer to the Appendix for a screenshot of the Fleet Manager Load Data window. For the purposes of this project, Microsoft Excel was used to extrapolate weight data from the Fleet Manager Software and perform the main data analysis as will be detailed in the following sections of the report.

4.4 Waste Generation Rates

The Region of Peel provides twice-a-week garbage collection and once-a-week recycling collection to multi-family buildings. Therefore, in order to obtain the total weekly generation for garbage it is necessary to have the total weight of garbage collection for both collection days. All weight data for both garbage and recycling was exported from the Fleet Manager Software into Microsoft Excel, where the total kilograms of garbage and recycling were summed per building and generation rates in kg/unit/week and diversion rates were calculated, where possible. Figure 3, by way of example, summarizes one week's waste generation data and diversion rates for select buildings. The following sections further summarize the findings for waste generation rates in both garbage and recycling streams and calculated diversion rates.

Figure 3 - Summary Table - Waste Generation and Diversion - Week of January 2, 2009

Front End Garbage Data						Cart Recycling Data			Diversion Rates
Truck 881	**Day 1**	**Day 2**	**Week's Total**	**# of Units**	**kg/unit/wk**	**Truck 673**	**Total kg**	**kg/unit/wk**	**%**
155 HILLCREST AVE	1358	1075	**2433**	342	**7.11**	155 HILLCREST AVE	**654**	**1.91**	**21%**
145 HILLCREST	1475	1500	**2975**	315	**9.44**				
135 HILLCREST AVE	1449	1276	**2725**	341	**7.99**	135 HILLCREST AVE	**406**	**1.19**	**13%**
5 KINGS CROSS RD	1466	644	**2110**	212	**9.95**	5 KINGS CROSS RD	n/a		
11 KNIGHTSBRIDGE RD	1729	1577	**3306**	180	**18.37**	11 KNIGHTSBRIDGE RD	n/a		
4 KINGS CROSS RD	1460	1333	**2793**	237	**11.78**	4 KINGS CROSS RD	n/a		
21 KNIGHTSBRIDGE RD	1091	952	**2043**	177	**11.54**	21 KNIGHTSBRIDGE RD	**162**	**0.92**	**7%**
17 KNIGHTSBRIDGE RD	1192	900	**2092**	177	**11.82**	17 KNIGHTSBRIDGE RD	**579**	**3.27**	**22%**
10 KENSINGTON RD	1112	571	**1683**	148	**11.37**	10 KENSINGTON RD	**410**	**2.77**	**20%**
1 KNIGHTSBRIDGE RD	303	236	**539**	90	**5.99**	1 KNIGHTSBRIDGE RD	n/a		
4 KNIGHTSBRIDGE RD	839	62	**901**	125	**7.21**	4 KNIGHTSBRIDGE RD	**330**	**2.64**	**27%**
10 KNIGHTSBRIDGE RD	688	735	**1423**	125	**11.38**	10 KNIGHTSBRIDGE RD	**108**	**0.86**	**7%**
3 KNIGHTSBRIDGE RD	1780	286	**2066**	309	**6.69**	3 KNIGHTSBRIDGE RD	n/a		
18 KNIGHTSBRIDGE RD	1135	n/a	**1135**	293	**3.87**	18 KNIGHTSBRIDGE RD	**176**	**0.60**	**13%**
25 KENSINGTON RD	1282	n/a	**1282**	210	**6.10**	25 KENSINGTON RD	n/a		
15 KENSINGTON RD	1629	n/a	**1629**	210	**7.76**	15 KENSINGTON RD	**576**	**2.74**	**26%**
Truck 882									
190 CLARK BLVD	1700	1590	**3290**	191	**17.23**	190 CLARK BLVD	**418**	**2.19**	**11%**
3 LISA ST	167	828	**995**	178	**5.59**	3 LISA ST	**172**	**0.97**	**15%**
4 LISA RD	1471	1132	**2603**	191	**13.63**	4 LISA RD	**366**	**1.92**	**12%**
5 LISA ST	914	896	**1810**	n/a		5 LISA ST	n/a		
8 LISA ST	994	754	**1748**	233	**7.50**	8 LISA ST	**310**	**1.33**	**15%**
9 LISA ST	1184	951	**2135**	192	**11.12**	9 LISA ST	**180**	**0.94**	**8%**
10 LISA ST	788	620	**1408**	180	**7.82**	10 LISA ST	n/a		
11 LISA ST	1175	1271	**2446**	188	**13.01**	11 LISA ST	**351**	**1.87**	**13%**
2 SILVER MAPLE CRT	1641	1225	**2866**	197	**14.55**	2 SILVER MAPLE CRT	n/a		
8 SILVER MAPLE CRT	1413	204	**1617**	295	**5.48**	8 SILVER MAPLE CRT	**242**	**0.82**	**13%**
6 SILVER MAPLE CRT	2185	915	**3100**	339	**9.14**	6 SILVER MAPLE CRT	**216**	**0.64**	**7%**
4 SILVER MAPLE CRT	1479	1649	**3128**	216	**14.48**	4 SILVER MAPLE CRT	n/a		

4.4.1 Garbage Generation

Garbage generation rates were calculated by adding the total kilograms collected on both collection days in the week, per building. The total kilograms were then divided by the number of units in the building to obtain a generation rate in kg/unit/week. Figure 4 summarizes the waste generation rates calculated for select buildings over the approximate 4 month data collection period. Overall, the average garbage generation rate was calculated to be 12.23 kg/unit/week. Of particular interest, is the fact that this generation rate very closely matches the calculated average garbage generation rate of 12.12 kg/unit/week from the 2005/2006 Stewardship Ontario Multi-Residential Waste Audits in Peel Region.

Figure 4 - Garbage Generation Rate Data

Truck 881	Weeks (kg/unit/week)															
	Nov. 24	Dec.1	Dec. 8	Dec. 15	Dec. 22	Jan. 5	Jan. 19	Jan. 26	Feb. 2	Feb. 9	Feb. 17	Feb. 23	Mar. 2	Mar. 9	Mar. 16	Average
155 HILLCREST AVE					11.31	7.11			6.17	8.25		5.86	8.45			**7.86**
145 HILLCREST				9.2	16.47	9.44			10.63	9.24	10.92	11.71	11.13			**11.09**
135 HILLCREST AVE				10.83	8.17	7.99			10.59		11.22	11.47	6.84			**9.59**
115 HILLCREST AVE				16.31	15.21					13.89	17.19		13.37			**15.19**
5 KINGS CROSS RD					21.05	9.95			14.27			15.85	15.39			**15.30**
11 KNIGHTSBRIDGE RD					16.77	18.37	18.76		12.69			16.14	14.14			**16.15**
4 KINGS CROSS RD						11.78			11.27			14.81	10.6			**12.12**
21 KNIGHTSBRIDGE RD	11.66				12.77	11.54			10.12			9.23	10.08			**10.90**
17 KNIGHTSBRIDGE RD	16.53				15.63	11.82			13.12			13.28	13.41			**13.97**
10 KENSINGTON RD	15.56			16.43	13.45	11.37			14.61			11.35	13.23			**13.71**
1 KNIGHTSBRIDGE RD				8.81	8.32	5.99	8.54		8.66			9.72	7.66			**8.24**
4 KNIGHTSBRIDGE RD						7.21	10.62		11.81			12.16	13.56			**11.07**
10 KNIGHTSBRIDGE RD	11.82				12.69	11.38	23.38		12.57			10.47	16.84			**14.16**
3 KNIGHTSBRIDGE RD					19.59	6.69	11.27		17.3			15.27	10.4			**13.42**
18 KNIGHTSBRIDGE RD	11.2			9.14			9.91		10.55			8.47	10.74			**10.00**
25 KENSINGTON RD	12.1			8.78			13.83		10.58			6.94	9.45			**10.28**
15 KENSINGTON RD	10.28			10.3			8.67		14.42			10.62	7.73			**10.34**
Truck 882																
30 HANSON RD				18.88	18.74				15.20	16.93		16.17	14.57	16.18	15.19	**16.48**
190 CLARK BLVD					22.49	17.23				11.76	19.54	10.68	16.45		17.70	**16.55**
3 LISA ST	11.73	9.21	10.79		13.29	5.59	9.77	7.37		9.61	10.94	7.22	10.72	7.52	13.40	**9.78**
4 LISA RD	14.63	12.26	14.71		21.91	13.63	12.47	14.42		12.91	11.47	12.42	10.17	11.97	10.85	**13.37**
8 LISA ST	8.55	8.44	8.74		9.10	7.5	7.09	12.99		8.66	8.00	8.26	8.52	9.36	7.20	**8.65**
9 LISA ST	11.15	13.38	10.73		11.88	11.12	11.46			12.55	10.65	9.68	10.79	10.99	10.80	**11.27**
10 LISA ST	10.62	8.39	9.17		15.51	7.82	10.17	14.34		12.23	11.20	9.19	8.09	10.59	10.49	**10.60**
11 LISA ST	13.11	11.36	10.83		10.59	13.01	12.15	12.69		10.41	12.84	12.73	11.06	11.26	11.52	**11.81**
2 SILVER MAPLE CRT	12.51	13.96	23.61		20.41	14.55	11.05	15.76		14.45	14.20	13.19	10.95	12.78	13.84	**14.71**
8 SILVER MAPLE CRT	12.68	10.96	10.51		12.27		18.49	10.72		13.34	12.03	7.47	15.18	11.08	12.44	**12.26**
6 SILVER MAPLE CRT	13.26	16.56	14.89		14.42	9.14	10.9	12.98		11.65	13.86	12.37	12.07	11.72	13.18	**12.85**
4 SILVER MAPLE CRT	14.24	11.1	14.21		20.23	14.48	12.62	12.03		9.94	11.83	12.67	11.28	12.37	12.48	**13.04**
															Total	**12.23**

In Figure 4, each column contains the weekly garbage generation rate for each corresponding building. No data was available wherever cells were left blank. The last column shows the average generation rate over the entire data collection period.

4.4.2 Cart-Based Recycling Generation

Figure 5 illustrates the generation rates calculated during the entire data collection period. The total kilograms of recycling collected per week, was divided by the total number of units per building to obtain the generation rate. The average recycling generation rate was calculated to be 1.70 kg/unit/week, which like the garbage generation rate, closely matched the waste audit findings in 2005/2006 of 1.82 kg/unit/week.

In Figure 5, each column contains the weekly cart-based recycling generation rate for each corresponding building. No data was available wherever cells were left blank. The last column shows the average generation rate over the entire data collection period.

Figure 5 - Cart-Based Recycling Generation Rate Data

Truck 881	Weeks (kg/unit/week)															Recycling
	Nov. 24	Dec.1	Dec. 8	Dec. 15	Dec. 22	Jan. 5	Jan. 19	Jan. 26	Feb. 2	Feb. 9	Feb. 17	Feb. 23	Mar. 2	Mar. 9	Mar. 16	Average
155 HILLCREST AVE				1.88	0.63	1.91										**1.47**
145 HILLCREST					1.12							1.64	0.8	0.72	1.29	**1.11**
135 HILLCREST AVE				2.39	1.10	1.19				0.94		1.45	0.9	1.64		**1.37**
115 HILLCREST AVE					0.37								1.32		1.41	**1.03**
5 KINGS CROSS RD																
11 KNIGHTSBRIDGE RD																
4 KINGS CROSS RD					1.51											**1.51**
21 KNIGHTSBRIDGE RD					2.01	0.92										**1.47**
17 KNIGHTSBRIDGE RD						3.27										**3.27**
10 KENSINGTON RD				2.12	1.70	2.77										**2.20**
1 KNIGHTSBRIDGE RD				3.9	2.41				4.63	5.03						**3.99**
4 KNIGHTSBRIDGE RD						2.64										**2.64**
10 KNIGHTSBRIDGE RD					0.94	0.86										**0.90**
3 KNIGHTSBRIDGE RD					0.24											**0.24**
18 KNIGHTSBRIDGE RD	1.04			1.46		0.6										**1.03**
25 KENSINGTON RD				2.1												**2.10**
15 KENSINGTON RD				2.19		2.74	2.24									**2.39**
Truck 882																
30 HANSON RD														1.72	1.77	**1.75**
190 CLARK BLVD					1.10	2.19										**1.65**
3 LISA ST	2.76		1.43		1.90	0.97	3.88	4.68		2.21						**2.55**
4 LISA RD	2.4	3.48			1.40	1.92		5.31		1.75						**2.71**
8 LISA ST			1.28		0.76	1.33				1.22	0.74					**1.07**
9 LISA ST	0.42		0.45		1.08	0.94	3.01			0.91						**1.14**
10 LISA ST	2.85				1.73					0.55						**1.71**
11 LISA ST		0.61				1.87		2.67		1.76						**1.73**
2 SILVER MAPLE CRT	0.24	0.51			0.78		3.2									**1.18**
8 SILVER MAPLE CRT	0.74	0.74	1.25		3.11	0.82				0.87	1.20					**1.25**
6 SILVER MAPLE CRT					1.03	0.64		0.29		0.73						**0.67**
4 SILVER MAPLE CRT					1.37					1.19	3.05					**1.87**
															Total	**1.70**

4.4.3 Diversion Rates

Based on the data from Figures 4 and 5, diversion rates have be calculated. Figure 6 summarizes the average diversion rates for select buildings. No data was available wherever cells were left blank. The average diversion rate was calculated to be 12 per cent. This closely matches the 2005/2006 waste audit data (13 per cent) and also the Region's calculated annual multi-residential diversion rate, based on tonnes collected (12 to 14 per cent) in the past 3 years.

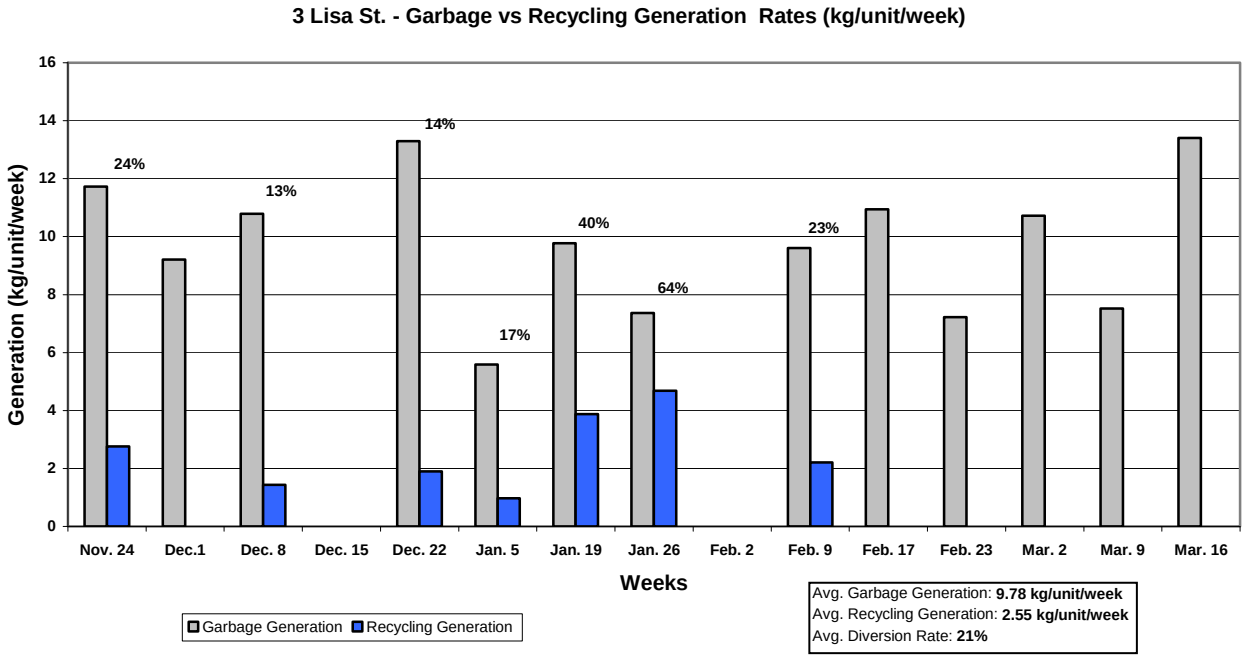
Figure 6 - Average Diversion Rates

Truck 881	Recycling Average Generation Rate (kg/unit/week)	Garbage Average Generation Rate (kg/unit/week)	% Diversion
155 HILLCREST AVE	1.47	7.86	**16%**
145 HILLCREST	1.11	11.09	**9%**
135 HILLCREST AVE	1.37	9.59	**13%**
115 HILLCREST AVE	1.03	15.19	**6%**
5 KINGS CROSS RD	n/a	15.30	
11 KNIGHTSBRIDGE RD	n/a	16.15	
4 KINGS CROSS RD	1.51	12.12	**11%**
21 KNIGHTSBRIDGE RD	1.47	10.90	**12%**
17 KNIGHTSBRIDGE RD	3.27	13.97	**19%**
10 KENSINGTON RD	2.20	13.71	**14%**
1 KNIGHTSBRIDGE RD	3.99	8.24	**33%**
4 KNIGHTSBRIDGE RD	2.64	11.07	**19%**
10 KNIGHTSBRIDGE RD	0.90	14.16	**6%**
3 KNIGHTSBRIDGE RD	0.24	13.42	**2%**
18 KNIGHTSBRIDGE RD	1.03	10.00	**9%**
25 KENSINGTON RD	2.10	10.28	**17%**
15 KENSINGTON RD	2.39	10.34	**19%**
Truck 882			
30 HANSON RD	1.75	16.48	**10%**
190 CLARK BLVD	1.65	16.55	**9%**
3 LISA ST	2.55	9.78	**21%**
4 LISA RD	2.71	13.37	**17%**
8 LISA ST	1.07	8.65	**11%**
9 LISA ST	1.14	11.27	**9%**
10 LISA ST	1.71	10.60	**14%**
11 LISA ST	1.73	11.81	**13%**
2 SILVER MAPLE CRT	1.18	14.71	**7%**
8 SILVER MAPLE CRT	1.25	12.26	**9%**
6 SILVER MAPLE CRT	0.67	12.85	**5%**
4 SILVER MAPLE CRT	1.87	13.04	**13%**
Total Average	1.70	12.23	**12%**

4.4.4 Building Example – Waste Generation Trend

With the available weight data, specific reporting for each building is possible. For example, Figure 7 shows the trend in waste generation for 3 Lisa St. In this figure, the garbage, recycling and diversion rates are mapped out over the entire data collection period. Due to the aforementioned limitations, certain weeks did not have complete generation data, thus diversion rates were not calculable. Calculated diversion rates are labelled at the top of each corresponding column. Note that two weeks in the middle of the chart indicates 40 and 64 per cent diversion rates, respectively. These diversion rates were highly unlikely to occur, therefore it is assumed that there has been an error made at the weight data collection stage. On average, 3 Lisa St. appears to generate less garbage and more recycling than average, thus contributing to their 21 per cent diversion rate, which is above average compared to the Region of Peel average diversion rate of 12 per cent.

Figure 7 - Building Example: 3 Lisa St.



4.4.5 Front-End Recycling Generation

In February 2009, the Region of Peel began the collection of single-stream recyclables in front-end containers. Approximately 120 locations received front-end recycling collection as part of the initial rollout. There are approximately 300 locations that are suitable to receive front-end recycling collection, to be phased in over the next year. The two front-loading garbage trucks equipped with the Loadman® onboard weigh scales have been used to collect data for the initial front-end recycling collection routes. The front-end recycling data presented in this report is preliminary data from the first three weeks of monitoring using the Loadman® onboard scales.

In the first three weeks of measuring the generation of recyclables from front-end bins, the average generation rate was found to be 1.94 kg/unit/week. This is slightly higher than the average calculated during data collection for recyclables in the cart-based collection system (1.70 kg/unit/week). A more direct comparison of the generation of recyclables before and after the implementation of front-end recycling collection can be made by just using the buildings selected for the cart-based pilot. In this direct comparison (buildings in Figure 6), the average generation of recyclables decreased after the implementation of front-end recycling. The average generation rate was found to be 1.44 kg/unit/week. Data indicates that overall waste generation (garbage and recycling) declined during the data collection period. Generation data for the garbage stream was not available for the first three weeks of

collecting data from front-end recycling locations; therefore a possible cause for the decrease in recycling generation could not be determined.

4.5 Waste Density

Over the data collection period, weights were compared to the type and size of bins to determine what the average densities were for each type and size of bin for garbage, cart recycling and front-end recycling. Bin weights varied, indicating that garbage and recycling containers may or may not have been full at the time of collection. The bin densities were calculated to provide a guide to what densities are currently present in the field. The calculated average densities are not meant to be a guideline to what maximum garbage and recycling densities can be achieved in the field.

4.5.1 Garbage Density

The average density of garbage as measured by the Loadman® onboard weigh scales over the data collection period is summarized in Figure 8 below. Un-compacted garbage was calculated to be 65 kg/yd^3 while compacted garbage was calculated to be 115 kg/yd^3 on average. The majority of garbage compactor bins in use in the Region of Peel are 3 yd^3 in capacity, therefore a garbage density of 128 kg/yd^3 is a more accurate representation of compacted garbage density. This density figure indicates that garbage is compacted at a ratio of 2:1, on average. This data will be very useful should the Region consider implementing some form of user pay system in the multi-family sector.

Figure 8 - Average Garbage Bin Density

Bin Size/Type	Average kg/yd3	Average Total kg
FL 8	**36**	286
FL 6	**45**	272
FL 4 Compacted	**103**	413
FL 4	**69**	278
FL 3 Compacted	**128**	383
FL 3	**91**	273
FL 2	**85**	171

Average kg/yd3 Compacted Waste =	**115**

Average kg/yd3 Un-Compacted Waste =	**65**

4.5.2 Recycling Density

The average density of recycling was calculated for both the cart-based and front-end collection systems. The cart-based recycling density was calculated using the total average net weight per route divided by the total number of carts collected to obtain an average number of kilograms per cart which was used to estimate the kg/yd^3. The front-end recycling density was calculated exactly like the garbage, where the onboard scales measured the total kilograms per bin by type and size. The results are summarized in Figure 9. Note that the average densities are fairly consistent between the cart-based and front-end calculated densities for recycling, i.e. from 38 to 40 kg/yd^3.

Figure 9 - Recycling Density - Cart-Based and Front-End Recycling

Front-End Recycling

Bin Size/Type	Average Kg	Average Density (kg/yd3)
FL 6.00	236	39
FL 4.00	146	36
FL 3.00	114	38
	Average kg/yd	**38**

Cart Recycling

Total Average Carts Collected on Route	Total Average Kg per Route	Average Kg/Cart	Average Kg/yd3
334	6681	20	**40**

5.0 Conclusions

The main objective of this project was to test the use of onboard weigh scales to measure the generation of garbage and recycling on a per building basis. Both the front fork-mounted and body-mounted Loadman® onboard weigh scale systems were successful in capturing waste generation data on a per building basis. The onboard weigh scale technology shows promise in tracking municipal waste collection in the multi-family sector.

Through the use of the Fleet Manager Software, information such as the total number of lifts, total kilograms collected and average waste densities were obtained and further data analysis was conducted by external software, namely Microsoft Excel. The Fleet Manager Software is capable of creating reports based on the user's preferences. For example, a report can be created to list the lifts performed at a particular building and weights associated with the lifts. However, in order to calculate a diversion rate or average waste density the data must be exported to an external program to do the math. The use of this software on a full-scale level would require a full-time staff commitment and further software development and integration to allow for more streamlined and programmable data exporting and manipulation.

Several constraints and limitations presented themselves throughout the pilot project. The project required a high degree of cooperation between the Region, Waste Management Corporation of Canada (WMCC), Creative Microsystems Inc. and Silver Top Supply Ltd. Due to the complex integration requirements of the scale technology between all parties involved, several stages in the implementation were delayed due to the requirement for approvals and computer system infrastructure design. This constraint should be kept in mind if a municipality wishes to implement a similar technology. Implementation may be more complex and time consuming when a collection contractor is involved as opposed to using the technology with an exclusively municipal fleet and computer network.

Another limitation in the project was the requirement for the driver's to use a bar-coded route sheet to capture the weight data for each lift or stop. When using a manual process such as bar-code scanning, there is a possibility for human error. In addition to this, the act of scanning a bar-coded route sheet is an extra step that the driver must take to capture the data. As the technology is capable of capturing the data, a possible next step would be to integrate the use of Radio Frequency Identification (RFID) technology with the Loadman® onboard weigh scale systems tested in this pilot. This makes data capture an automated process and removes the reliance on the driver to record the stop information with bar codes.

Due to the fact that only two front-end garbage trucks and two top-loading recycling trucks were equipped with the onboard scales, the pilot was subject to truck breakdowns. As this was a pilot project and a limited number of vehicles were equipped with scales, this was expected and did not impact the evaluation of the scale technology. Should a full scale system be implemented this would be less of an issue as all trucks would be equipped with onboard scales (including spare vehicles).

The accuracy of both onboard weigh scale systems is acceptable for tracking waste generation on a per building basis. The average difference in reported weights was 4 kg per lift for the front fork-mounted onboard weigh scale system and 7 kilograms per stop or 1 kilogram per cart for the body-mounted onboard weigh scales collecting recyclables from 95 gallon carts. Accurate generation rates in kg/building or kg/unit/week can be calculated along with a diversion weight, if both garbage and recycling weights are available for the weekly data collection period.

Overall, both onboard weigh scale systems tested in this pilot have proven to be a useful technology that can assist municipalities to track waste generation rates in the multi-family sector. They offer a cost effective method of capturing this data on a continual basis and can potentially be used to measure changes in generation before and after new waste management programs have been implemented. For example, the Region of Peel began front-end recycling collection; the onboard scales were used to compare recycling generation rates before and after the new collection service was introduced. Specific buildings may also be targeted for increased promotion and education should their recycling rates be very low. There is great potential in the technology tested in this pilot, as the data can be used for multiple purposes to help address the problem of low diversion in the often hard to reach multi-family sector.

References

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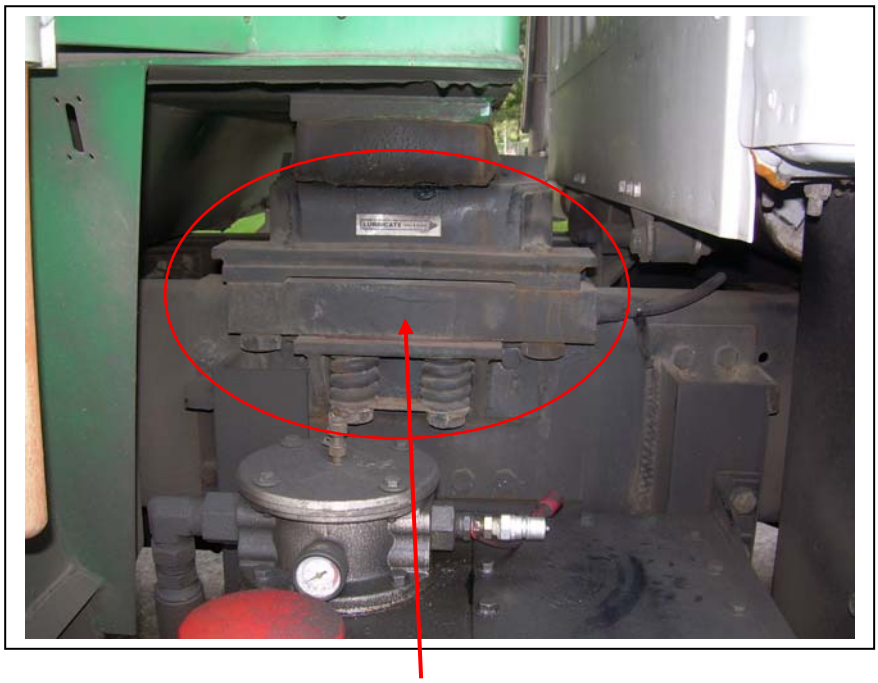
APPENDIX

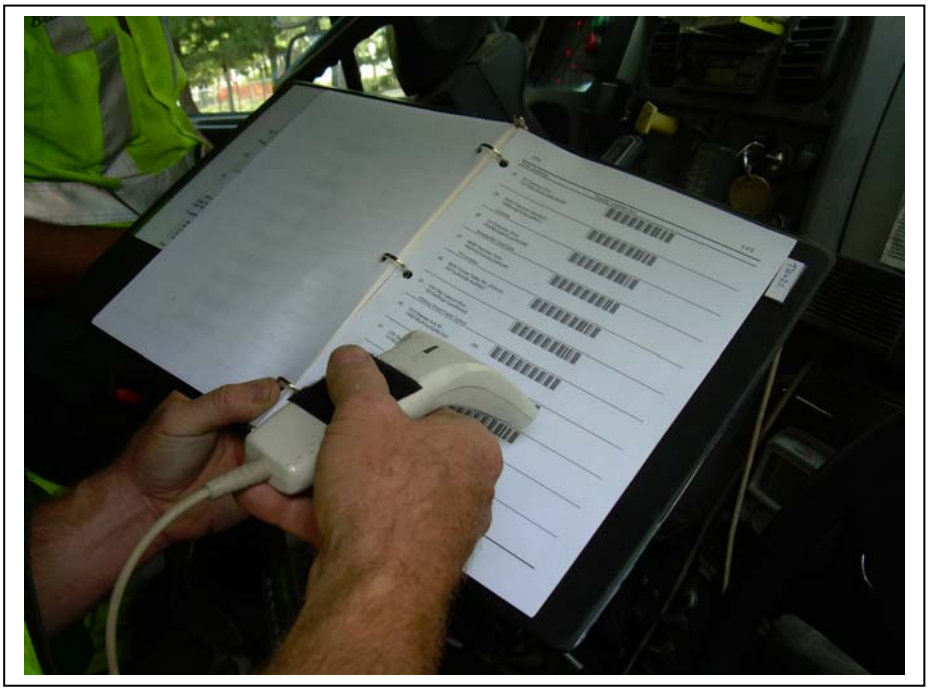
Loadman® Onboard Scale Meter



Body-Mounted Load Cell – Front Chassis

Truck Cab – Scale Meter and Smash Box #1

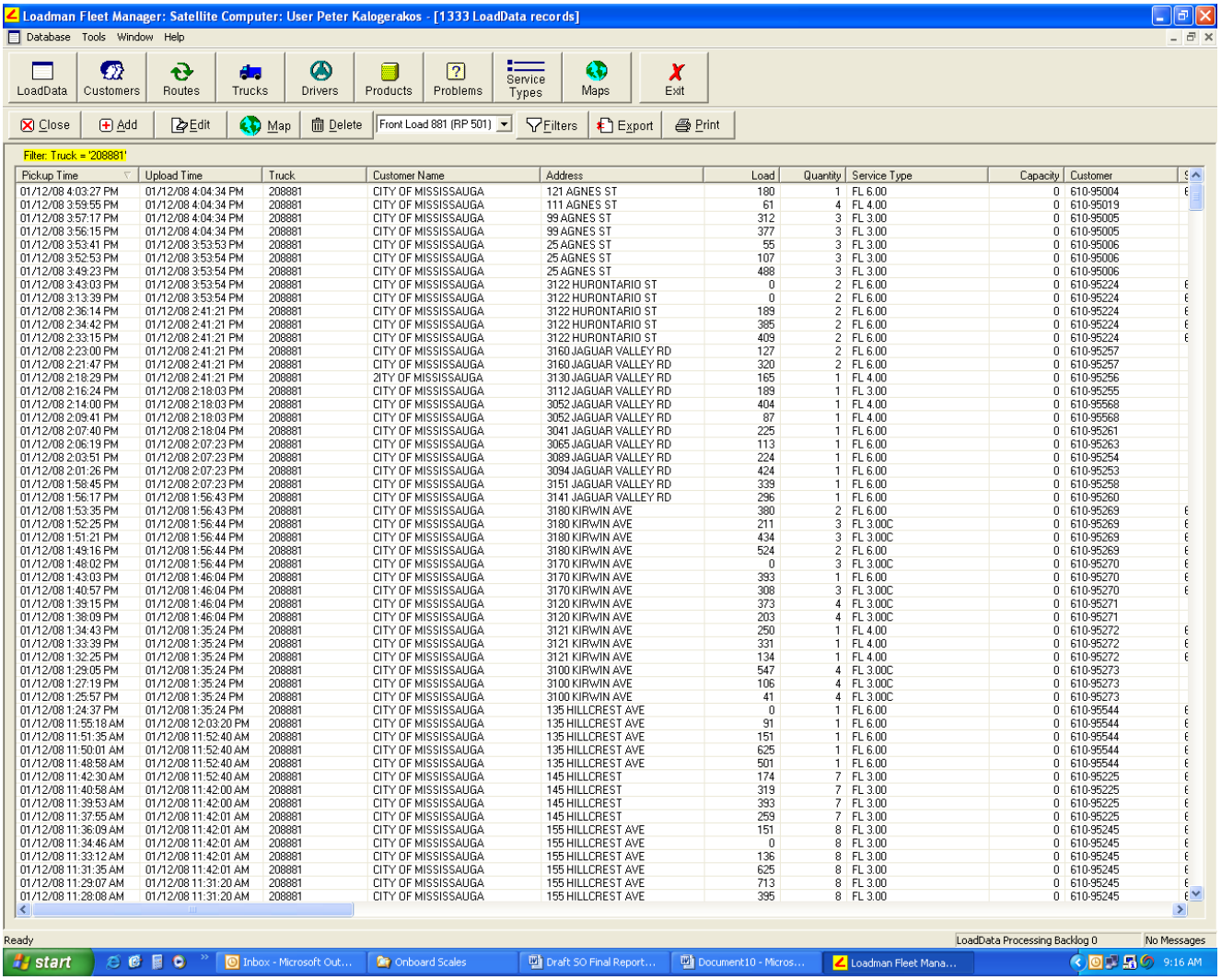
Smash Box #2



Bar-coded Route Sheets

On-route Driver Training

Fleet Manager Software Screenshot



Pickup Time	Upload Time	Truck	Customer Name	Address	Load	Quantity	Service Type	Capacity	Customer
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01/12/08 3:59:55 PM	01/12/08 4:04:34 PM	208881	CITY OF MISSISSAUGA	111 AGNES ST	61	4	FL 4.00	0	610-95019
01/12/08 3:57:17 PM	01/12/08 4:04:34 PM	208881	CITY OF MISSISSAUGA	99 AGNES ST	312	3	FL 3.00	0	610-95005
01/12/08 3:56:15 PM	01/12/08 4:04:34 PM	208881	CITY OF MISSISSAUGA	99 AGNES ST	377	3	FL 3.00	0	610-95005
01/12/08 3:53:41 PM	01/12/08 3:53:53 PM	208881	CITY OF MISSISSAUGA	25 AGNES ST	55	3	FL 3.00	0	610-95006
01/12/08 3:52:53 PM	01/12/08 3:53:54 PM	208881	CITY OF MISSISSAUGA	25 AGNES ST	107	3	FL 3.00	0	610-95006
01/12/08 3:49:23 PM	01/12/08 3:53:54 PM	208881	CITY OF MISSISSAUGA	25 AGNES ST	488	3	FL 3.00	0	610-95006
01/12/08 3:43:03 PM	01/12/08 3:53:54 PM	208881	CITY OF MISSISSAUGA	3122 HURONTARIO ST	0	2	FL 6.00	0	610-95224
01/12/08 3:13:39 PM	01/12/08 3:53:54 PM	208881	CITY OF MISSISSAUGA	3122 HURONTARIO ST	0	2	FL 6.00	0	610-95224
01/12/08 2:36:14 PM	01/12/08 2:41:21 PM	208881	CITY OF MISSISSAUGA	3122 HURONTARIO ST	189	2	FL 6.00	0	610-95224
01/12/08 2:34:42 PM	01/12/08 2:41:21 PM	208881	CITY OF MISSISSAUGA	3122 HURONTARIO ST	385	2	FL 6.00	0	610-95224
01/12/08 2:33:15 PM	01/12/08 2:41:21 PM	208881	CITY OF MISSISSAUGA	3122 HURONTARIO ST	409	2	FL 6.00	0	610-95224
01/12/08 2:23:00 PM	01/12/08 2:41:21 PM	208881	CITY OF MISSISSAUGA	3160 JAGUAR VALLEY RD	127	2	FL 6.00	0	610-95257
01/12/08 2:21:47 PM	01/12/08 2:41:21 PM	208881	CITY OF MISSISSAUGA	3160 JAGUAR VALLEY RD	320	2	FL 6.00	0	610-95257
01/12/08 2:18:29 PM	01/12/08 2:41:21 PM	208881	2ITY OF MISSISSAUGA	3130 JAGUAR VALLEY RD	165	1	FL 4.00	0	610-95256
01/12/08 2:16:24 PM	01/12/08 2:18:03 PM	208881	CITY OF MISSISSAUGA	3112 JAGUAR VALLEY RD	189	1	FL 3.00	0	610-95255
01/12/08 2:14:00 PM	01/12/08 2:18:03 PM	208881	CITY OF MISSISSAUGA	3052 JAGUAR VALLEY RD	404	1	FL 4.00	0	610-95568
01/12/08 2:09:41 PM	01/12/08 2:18:03 PM	208881	CITY OF MISSISSAUGA	3052 JAGUAR VALLEY RD	87	1	FL 4.00	0	610-95568
01/12/08 2:07:40 PM	01/12/08 2:18:04 PM	208881	CITY OF MISSISSAUGA	3041 JAGUAR VALLEY RD	225	1	FL 6.00	0	610-95261
01/12/08 2:06:19 PM	01/12/08 2:07:23 PM	208881	CITY OF MISSISSAUGA	3065 JAGUAR VALLEY RD	113	1	FL 6.00	0	610-95263
01/12/08 2:03:51 PM	01/12/08 2:07:23 PM	208881	CITY OF MISSISSAUGA	3089 JAGUAR VALLEY RD	224	1	FL 6.00	0	610-95254
01/12/08 2:01:26 PM	01/12/08 2:07:23 PM	208881	CITY OF MISSISSAUGA	3094 JAGUAR VALLEY RD	424	1	FL 6.00	0	610-95253
01/12/08 1:58:45 PM	01/12/08 2:07:23 PM	208881	CITY OF MISSISSAUGA	3151 JAGUAR VALLEY RD	339	1	FL 6.00	0	610-95258
01/12/08 1:56:17 PM	01/12/08 1:56:43 PM	208881	CITY OF MISSISSAUGA	3141 JAGUAR VALLEY RD	296	1	FL 6.00	0	610-95260
01/12/08 1:53:35 PM	01/12/08 1:56:43 PM	208881	CITY OF MISSISSAUGA	3180 KIRWIN AVE	380	2	FL 6.00	0	610-95269
01/12/08 1:52:25 PM	01/12/08 1:56:44 PM	208881	CITY OF MISSISSAUGA	3180 KIRWIN AVE	211	3	FL 3.00C	0	610-95269
01/12/08 1:51:21 PM	01/12/08 1:56:44 PM	208881	CITY OF MISSISSAUGA	3180 KIRWIN AVE	434	3	FL 3.00C	0	610-95269
01/12/08 1:49:16 PM	01/12/08 1:56:44 PM	208881	CITY OF MISSISSAUGA	3180 KIRWIN AVE	524	2	FL 6.00	0	610-95269
01/12/08 1:48:02 PM	01/12/08 1:56:44 PM	208881	CITY OF MISSISSAUGA	3170 KIRWIN AVE	0	3	FL 3.00C	0	610-95270
01/12/08 1:43:03 PM	01/12/08 1:46:04 PM	208881	CITY OF MISSISSAUGA	3170 KIRWIN AVE	393	1	FL 6.00	0	610-95270
01/12/08 1:40:57 PM	01/12/08 1:46:04 PM	208881	CITY OF MISSISSAUGA	3170 KIRWIN AVE	308	3	FL 3.00C	0	610-95270
01/12/08 1:39:15 PM	01/12/08 1:46:04 PM	208881	CITY OF MISSISSAUGA	3120 KIRWIN AVE	373	4	FL 3.00C	0	610-95271
01/12/08 1:38:09 PM	01/12/08 1:46:04 PM	208881	CITY OF MISSISSAUGA	3120 KIRWIN AVE	203	4	FL 3.00C	0	610-95271
01/12/08 1:34:43 PM	01/12/08 1:35:24 PM	208881	CITY OF MISSISSAUGA	3121 KIRWIN AVE	250	1	FL 4.00	0	610-95272
01/12/08 1:33:39 PM	01/12/08 1:35:24 PM	208881	CITY OF MISSISSAUGA	3121 KIRWIN AVE	331	1	FL 4.00	0	610-95272
01/12/08 1:32:25 PM	01/12/08 1:35:24 PM	208881	CITY OF MISSISSAUGA	3121 KIRWIN AVE	134	1	FL 4.00	0	610-95272
01/12/08 1:29:05 PM	01/12/08 1:35:24 PM	208881	CITY OF MISSISSAUGA	3100 KIRWIN AVE	547	4	FL 3.00C	0	610-95273
01/12/08 1:27:19 PM	01/12/08 1:35:24 PM	208881	CITY OF MISSISSAUGA	3100 KIRWIN AVE	106	4	FL 3.00C	0	610-95273
01/12/08 1:25:57 PM	01/12/08 1:35:24 PM	208881	CITY OF MISSISSAUGA	3100 KIRWIN AVE	41	4	FL 3.00C	0	610-95273
01/12/08 1:24:37 PM	01/12/08 1:35:24 PM	208881	CITY OF MISSISSAUGA	135 HILLCREST AVE	0	1	FL 6.00	0	610-95544
01/12/08 11:55:18 AM	01/12/08 12:03:20 PM	208881	CITY OF MISSISSAUGA	135 HILLCREST AVE	91	1	FL 6.00	0	610-95544
01/12/08 11:51:35 AM	01/12/08 11:52:40 AM	208881	CITY OF MISSISSAUGA	135 HILLCREST AVE	151	1	FL 6.00	0	610-95544
01/12/08 11:50:01 AM	01/12/08 11:52:40 AM	208881	CITY OF MISSISSAUGA	135 HILLCREST AVE	625	1	FL 6.00	0	610-95544
01/12/08 11:48:58 AM	01/12/08 11:52:40 AM	208881	CITY OF MISSISSAUGA	135 HILLCREST AVE	501	1	FL 6.00	0	610-95544
01/12/08 11:42:30 AM	01/12/08 11:52:40 AM	208881	CITY OF MISSISSAUGA	145 HILLCREST	174	7	FL 3.00	0	610-95225
01/12/08 11:40:58 AM	01/12/08 11:42:00 AM	208881	CITY OF MISSISSAUGA	145 HILLCREST	319	7	FL 3.00	0	610-95225
01/12/08 11:39:53 AM	01/12/08 11:42:00 AM	208881	CITY OF MISSISSAUGA	145 HILLCREST	393	7	FL 3.00	0	610-95225
01/12/08 11:37:55 AM	01/12/08 11:42:01 AM	208881	CITY OF MISSISSAUGA	145 HILLCREST	259	7	FL 3.00	0	610-95225
01/12/08 11:36:09 AM	01/12/08 11:42:01 AM	208881	CITY OF MISSISSAUGA	155 HILLCREST AVE	151	8	FL 3.00	0	610-95245
01/12/08 11:34:46 AM	01/12/08 11:42:01 AM	208881	CITY OF MISSISSAUGA	155 HILLCREST AVE	0	8	FL 3.00	0	610-95245
01/12/08 11:33:12 AM	01/12/08 11:42:01 AM	208881	CITY OF MISSISSAUGA	155 HILLCREST AVE	136	8	FL 3.00	0	610-95245
01/12/08 11:31:35 AM	01/12/08 11:42:01 AM	208881	CITY OF MISSISSAUGA	155 HILLCREST AVE	625	8	FL 3.00	0	610-95245
01/12/08 11:29:07 AM	01/12/08 11:31:20 AM	208881	CITY OF MISSISSAUGA	155 HILLCREST AVE	713	8	FL 3.00	0	610-95245
01/12/08 11:28:08 AM	01/12/08 11:31:20 AM	208881	CITY OF MISSISSAUGA	155 HILLCREST AVE	395	8	FL 3.00	0	610-95245

Front-end Garbage Collection Truck

Note:

- **"Load " column lists the weight/lift (kg)**
- **"Quantity" column indicates total number of bins owned by building**
- **"Service Type" column indicates type and size of garbage bin lifted**