ENGINEERING

McMaster University

Designing a Materials Recovery Facility For Our Community

McMaster Recycling Plant Design

ENGINEER 2PX3

Tutorial 15

Team Recycling-39

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The student is responsible for performing the required work in an honest manner, without plagiarism and cheating. Submitting this work with my name and student number is a statement and understanding that this work is my own and adheres to the Academic Integrity Policy of McMaster University.

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x Shabab Rahman

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Executive Summary

In the last two centuries, the production of waste has become rampant across the world. A globally recognized solution, recycling, was perceived to be effective in remedying this issue (Wilson & Velis, 2015). However, as shown by recent headlines in East and South Asia, western countries have become complacent in their recycling systems, sending barely recyclable and essentially trash to foreign systems expecting salvageable materials (Rapoza, 2020). The pushback to this was inevitable, and now many communities are reckoning with their recycling strategies which are often placed in the hands of third party companies. Taking responsibility for this on a local level is a powerful tool. By designing a materials recovery facility for McMaster University, students and staff can effectively take control of their own waste recovery and ensure high quality standards are meant to extend the life cycle of these materials.

Key decisions that need to be made are the facility's location, its storage capabilities for the waste, the extent to which the facility will be automated, and the sourcing of the process units. In this report, the location of Lot M was selected as it is at a comfortable distance from campus life and protected environmental areas, which the other two locations, JHE and the 10-acre field, are not. Completely covered and above ground storage was decided upon as underground and open storage would have led to contamination of the local ecosystems and water outlets. The facility will also operate on a 24/7 hour basis to support the surrounding businesses as well. This will allow the McMaster community to also take responsibility for the waste they produce through these outlets. Finally, a specific sorting system for plastics will be implemented by utilizing an IR sensor to differentiate between plastics utilizing 9 different characteristics.

All of these design options enable the framework of a general materials recovery facility to be generated. This framework would benefit substantially from additional consultations with local regulatory authorities and university waste services to fine-tune important aspects. Once these discussions are held, a more concrete proposal for an MRF can be implemented.

Introduction

Modern life is inseparable from plastic due to its light, waterproof and cheap characteristics. However, the main components of ordinary plastic products are stable substances such as polyethylene, polypropylene, and polyvinyl chloride. The plastic products produced with these raw materials are not easy to decompose and cause pollution of the surrounding environment. According to surveys, mixed containers occupied 12.3percent of the overall garbage composition of McMaster University in 2019 [Figure 1], which is approximately equal to 300tons of mixed container waste each year. Among all these wastes, only thirty percent are recycled. As a result, the design is going to help McMaster University and the surrounding community to reduce the waste of raw materials, lower energy consumption and conserve natural resources. Moreover, not only will this facility work to decrease the cost of waste disposal for the campus, the McMaster recycling plant, if properly designed, can also serve as a potential learning environment for engineering students (Waste Reduction Group Inc., 2019)

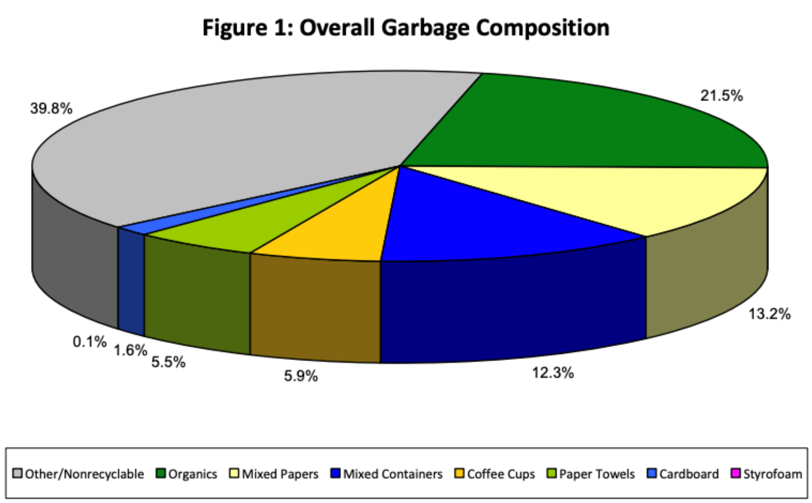


Figure 1 The overall composition pf garbage produced at McMaster University. (Waste Reduction Group Inc., 2019)

The function of Material Recovery Facilities (MRFs) is to take municipal and commercial waste streams and extract and isolate recyclable products from said waste stream [3]. In this project, the goal is to design a materials recovery facility near McMaster that effectively separates more recyclable items from locally generated waste to minimize the impact that the University and its surrounding community have on the environment.

The design solution will mainly consider two points, one is the location selection of MRF construction, and the other is the implementation of the sorting algorithm for the seven types of plastic recyclables. The McMaster PRESEID method will be applied to consider the constraints through performance, socio-cultural, regulatory, and environmental factors during the design process.

There are several important parameters to consider. The environmental impact of the MRFs on the surrounding neighbourhoods such as noise and pollution. Whether the construction of the MRFs follows the Ontario waste management regulations. The safety of the MRFs to students and staff. The amount of waste throughput can handle per day and the corresponding carbon footprint and energy consumption. The performance of the MRF should produce a high sorting result. The final design will be presented based on these important parameters and the most ideal will be selected.

Conceptual Design

After going through a rigorous decision making process between three potential locations for the McMaster Recycling Plant, we had to weigh off one option as a better one compared to the other two. Many factors influenced our decisions and each of them had a different level of importance that helped us further analyze the positive and negative impacts of each option

Design alternative:

→ Parking Lot M: Located at a good distance from the main campus, this is a prime location considering the health and safety of the McMaster students. Besides, being further apart from the academic buildings, the noise generated from process units will not impact the students and staff on campus. Having sufficient space, this location can facilitate large conveyor belts carrying an appropriate amount of recycling waste. Based on different material properties, different sensors can be used to distinguish between the waste materials and then the automated separating units like fine screen, ballistic, eddy current and magnetic separator can be used to split the materials according to their corresponding properties. Having a constructed base, this facility can be utilized for elevated storage and operation, which is one of the requirements of the Ontario Waste Management regulations to avoid land pollution. Being further apart from the Cootes Paradise, the location reduces the risk of affecting the nature and wildlife near the McMaster campus. Transportation of waste to this location is however a challenge since it’s the furthest among all the possible options.

→ 10 acre field: Being on the north side of the campus, this location is spacious and closer to the main campus making it easier to transport the waste from throughout the campus. With adequate space, this location is also accessible by heavy processing machinery like a large conveyor belt, heavily automated process units like a magnetic separator, ballistic separator, eddy current separator and fine screen. The field, unlike the parking lot M, does not have a constructed base, meaning it will add up a big chunk of cost which might not a good impression on the community. Moreover, being right beside the athletic center, the operation of the recycling plant might affect the McMaster athletes as it might generate some noise and lead up to a certain level of pollution. Moreover, being a neighbour to the Cootes paradise, a recycling plant at this location threatens the natural land and the wildlife surrounding it with the possibility of pollution.

→ JHE basement: Restricted within a certain area, it is very challenging to operate heavy process units at this location. A lower level of automation will result in reduced sorting capacity, hence affecting the performance. Being right at the heart of the campus, it can be a source of disturbance to a lot of students who attends the classes at or near JHE, as it will be generating some noise during operation. Moreover, having an underground facility is also against the limitation of having elevated storage and operation location, set by the Ontario Waste Management Regulations. Considering the safety of the students and staff, this is the least desired location as any type of accident would directly affect the people on campus. The good side of this location is that waste can easily be transported to this place.

Decision matrices:

To weigh off the competing factors that come with the 3 possible options, we decided to construct a few decision matrices that will help us consolidate our decision as it will help to different weights to the factors based on their importance and directly compare the options. This will guide us to choose the right option with the highest overall weight. We will develop the decision matrices following the PERSEID layers.

Decision Matrices: (Weights are given on a scale of 10 based on importance)

Performance:

Categories	Weight	Parking Lot M	10 Acre Field	JHE Basement
Automated Units	3	3*8 = 24	3*6 = 18	3*3 = 9
Processing Time (Faster)	3	3*9 = 27	3*8 = 24	3*5 = 15
Capacity	4	4*5 = 20	4*5 = 20	4*3 = 12
Total	10	**71**	62	44

Socio-Cultural:

Categories	Weight	Parking Lot M	10 Acre Field	JHE Basement
Safety	4	4*7 = 28	4*4 = 16	4*2 = 8
Cost Reduction	2	2*3 = 6	2*2 = 4	2*5 = 10
Noise Level Reduction	4	4*6 = 24	4*3 = 12	4*1 = 4
Total	10	**58**	32	22

Regulatory:

Categories	Weight	Parking Lot M	10 Acre Field	JHE Basement
Storage	4	4*5 = 20	4*4 = 16	4*2 =8
Transport	2	2*2 = 4	2*4 = 8	2*5 = 10
Cleanliness	4	4*5 = 20	4*3 = 12	4*2 = 8
Total	10	**44**	36	26

Environmental:

Categories	Weight	Parking Lot M	10 Acre Field	JHE Basement
Reduced Land pollution	3	3*5 = 15	3*2 = 6	3*3 = 9
Wildlife Friendliness	4	4*4 = 16	4*2 = 8	4*5 = 20
Water body protection	3	3*4 = 12	3*2 = 6	3*3 = 9
Total	10	**43**	20	38

Based on the comprehensive analysis following the PERSEID layers, we can see that parking lot M leads in every category meeting the criteria we have set in our decision-making process.

Design evaluation:

The illustration using the weighted decision matrix gives us an in depth understanding of the important factors that help us determine our final design. The Parking Lot M design has a substantial design advantage over the other options with its increased ability to facilitate more automated units and boost the productivity of the recycling plant clearly outlines why it is the strongest contender for the category. The 10 acre field is another possible option that misses out slightly on its ability to sort the materials faster. JHE on the other hand with its limited capacity to hold automated units falls way behind when it comes down to performing.

Parking Lot M being the furthest from the main campus affects the students to the least extent and does not hinder the regular campus life as the noise generated from operation does not reach the people on campus. Besides, it is also the least impactful if any unwanted accident occurs but being an open space, the cost of construction is a little higher for this option. The 10 acre field is a more expensive option since, it is not developed at all, and it is also safer compared to the parking lot M as it is closer to the campus and any incident on site might affect people nearby. The noise level might also disturb the athletes at McMaster. JHE being the cheapest option meets none of the criteria since it is right at the center and anything unwanted can have undesirable effects.

Sufficient storage ability on an elevated space helps the parking lot M to meet the regulatory criteria and also maintain the cleanliness level inside the facility although the transportation of waste is a little difficult to the location. The 10 acre field and JHE are easier for transportation. However 10 acre field has slightly less storage capacity than the parking lot M and might not be the best when it's a matter of cleanliness while JHE could be the least clean option and with the least storage making it the least desired choice.

Being split from the natural reserves near campus, parking lot M once again proves itself as the best location keeping the land and water pollution level to a minimum. It is also one of the most friendly to the wildlife

Simulation Insights

The provided operating frequency is [10,5,2,1]HZ. Considering the environmental impact of the sensor cause more noise operating at high frequency. The final selection of the operating frequency is 5HZ. By changing the parameters of speed and frequency, an observation is found that the conveyor speed(cm/s) should match the sampling frequency to avoid missing containers.

Infrared (IR) sensor has the advantages of low cost and high accuracy but with a disadvantage of HDPE and LDPE classification; Raman Spectroscopy sensor has the advantage to classify HDPE and LDPE but lacks the overall accuracy compared to IR. Based on the pros and cons, and the pre provided supporting document of the IR sensor. The python code implementation will be using the IR technique. Below is the plotting figure of nine different types of plastics transmittance VS wavenumber.

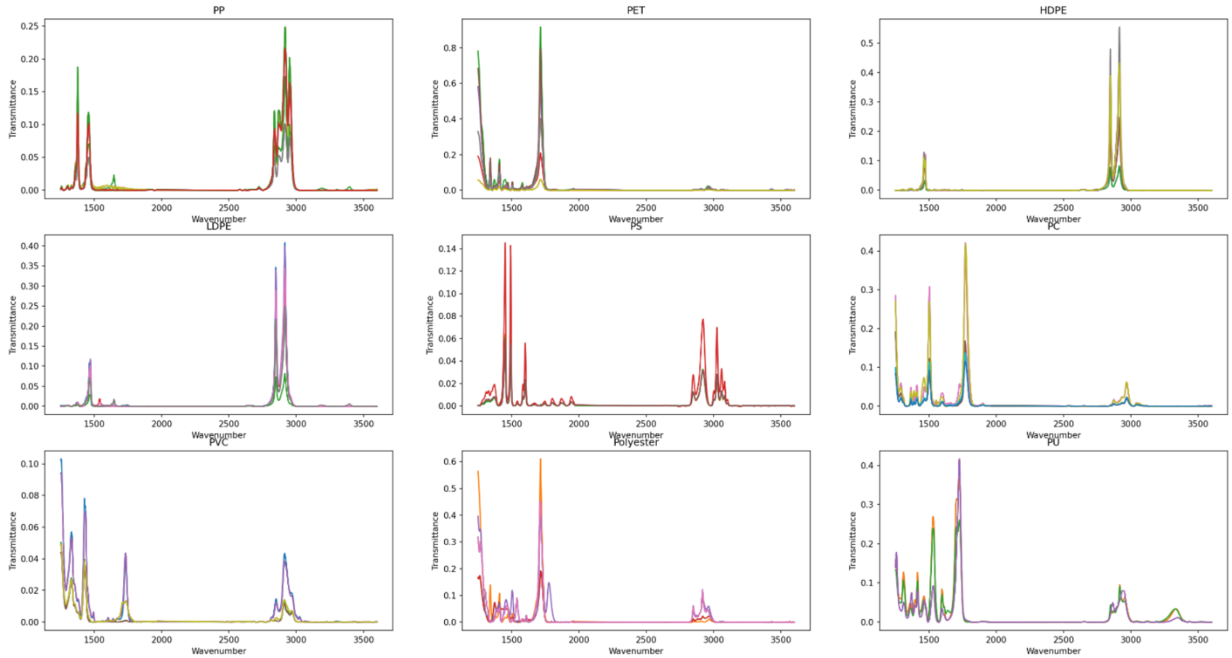
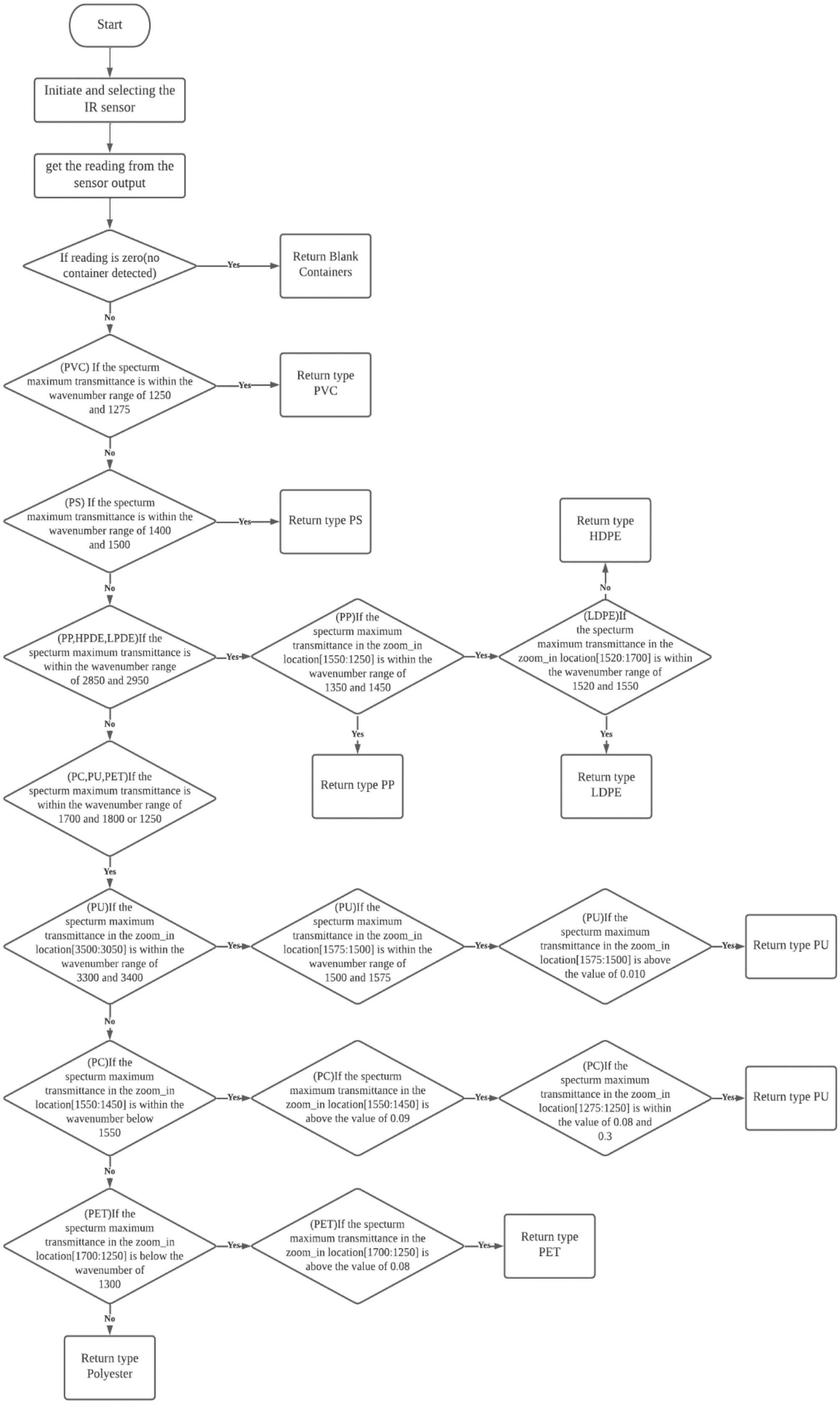


Figure 2 Nine different types of material properties

It shows nine different types of material properties. By using the provided Python third Libray module-Pandas, both the special transmittance and corresponding waveforms from the plot can be obtained by using special commands.

As a result, by making analyses of the plot figure, a flowchart of the whole sorting process is pre made to better help implement the algorithm.


Start
Initiate and selecting the IR sensor
get the reading from the sensor output
If reading is zero(no container detected)
Yes
Return Blank Containers
No
(PVC) If the specturm maximum transmittance is within the wavenumber range of 1250 and 1275
Yes
Return type PVC
No
(PS) If the specturm maximum transmittance is within the wavenumber range of 1400 and 1500
Yes
Return type PS
No
(PP,HPDE,LPDE)If the specturm maximum transmittance is within the wavenumber range of 2850 and 2950
Yes
(PP)If the specturm maximum transmittance in the zoom_in location[1550:1250] is within the wavenumber range of 1350 and 1450
Yes
Return type PP
Yes
(LDPE)If the specturm maximum transmittance in the zoom_in location[1520:1700] is within the wavenumber range of 1520 and 1550
Yes
Return type LDPE
No
Return type HDPE
No
(PC,PU,PET)If the specturm maximum transmittance is within the wavenumber range of 1700 and 1800 or 1250
Yes
(PU)If the specturm maximum transmittance in the zoom_in location[3500:3050] is within the wavenumber range of 3300 and 3400
Yes
(PU)If the specturm maximum transmittance in the zoom_in location[1575:1500] is within the wavenumber range of 1500 and 1575
Yes
(PU)If the specturm maximum transmittance in the zoom_in location[1575:1500] is above the value of 0.010
Yes
Return type PU
No
(PC)If the specturm maximum transmittance in the zoom_in location[1550:1450] is within the wavenumber below 1550
Yes
(PC)If the specturm maximum transmittance in the zoom_in location[1550:1450] is above the value of 0.09
Yes
(PC)If the specturm maximum transmittance in the zoom_in location[1275:1250] is within the value of 0.08 and 0.3
Yes
Return type PU
No
(PET)If the specturm maximum transmittance in the zoom_in location[1700:1250] is below the wavenumber of 1300
Yes
(PET)If the specturm maximum transmittance in the zoom_in location[1700:1250] is above the value of 0.08
Yes
Return type PET
No
Return type Polyester

Final Proposed Design

Location

The location of the facility was selected to be Lot M, a parking lot located on the North-West side of campus. Not only is the land of this area already paved, reducing construction costs, but it is adequately distant from the environmentally protected area of Cootes Paradise. The location of the 10 acre field was disqualified due to its proximity to this. Furthermore, when considering the safety of students and staff, industrial vehicles would be required to travel through many commonly used routes to transport pre and post recycled materials to their destination. Another location, the first floor of JHE, was also considered. While somewhat equipped with industrial tools and easily accessible for students, it was dismissed as a viable option due to socio-cultural concerns. Specifically, high noise and odour levels will be likely to impact students and staff, which also violated McMaster's Health and Safety Policy. Additionally, the placement of an MRF in JHE would violate Ontario Waste Management regulations as the space available is not enough for the long-term storage of waste materials.

The settled area of Lot M also allows the facility to be placed completely above ground. This ensures a substantially reduced probability of groundwater contamination, eliminating that environmental hazard. Finally, by allowing the facility to not be limited by an already existing building like JHE, space will not be a deciding factor for what process units are selected, addressing a technical performance constraint. Nevertheless, every process necessary for the functioning of the facility will have to be completely enclosed inside the buildings. This is necessary to adhere to all three levels of regulatory oversight when considering the necessary capacity to store waste, prevent the release of great sound and odour, and protect the waste from adverse weather. Specifically, by enclosing the pre-and post-processed waste, the probability of waste escaping the facility is reduced, ensuring environmental degradation is minimized.

Process Unit Methodology

When considering what process units to select for the facility, it was determined that they should be purchased from established manufacturers. This allows the facility to be equipped with state-of-the-art process units that have already been thoroughly tested for their energy consumption. While designing custom units would have allowed a precise system for McMaster's specific waste production, this would have also made it more difficult to ensure energy consumption standards are being met over the long term. Furthermore, by using established sources for these systems, public perception would be more lenient towards reducing the human components of the system and increasing the automation of the overall process.

Facility Operation

Additionally, by allowing this MRF to operate on a 24-hour basis, the need to utilize heavy vehicular transportation during the day when the campus is most populated will be reduced. This will decrease the likelihood of idling due to traffic, reduce emissions and adhere to environmental constraints, and reduce the chances of incidents where the safety of students and staff is endangered. A highly automated system will also allow minimal staffing as well and will allow the facility to operate for long hours. Finally, with a 24-hour operation, the facility can accommodate the waste generated by surrounding businesses as well. Not only will this allow the McMaster community to more thoroughly take responsibility for the far-reaching impacts of its local waste generation but this will also allow the positive perception to counteract the potential negative reaction to a mostly automated facility. The increased length of operation of the facility will undoubtedly consume more energy but this should be countered by the sourcing of green energy by local hydroelectric facilities.

Sorting Simulation

```
Results for running the simulation in "training" mode:
Total missed containers = 0
Total sorted containers = 1673
Total mistyped containers = 327

2000 containers are processed in 7377.10 seconds

Process finished with exit code 0
```

Figure 3 Output of the simulation

The final sorting result is shown in the right figure. By following the pre-made flowchart, the detecting order is following[PVC, PS, PP_HPDE_LDPE, PC_PU_PET] with specific functions definitions outside the main function. After each type function definition, the sanity check method will be applied to determine the functionality of this method. The sanity check method used for this algorithm is to watch the output result of incorrectly identified containers; by applying a quick search function for the unsorted containers (Ctrl + F), the specific searched type can be found or not (sorted successfully). Therefore, within the total output of 2000 different types of containers, the ideal sanity check applied on each specific type should be zero (not found). However, because of the super close material type similarity under IR of LDPE and HDPE. We found it difficult to minimize the incorrectly identified containers of these two types. Through discussion, we came up with an improvement to be able to classify these two types in future which is passing the LDPE and HDPE container to the Raman Spectroscopy sensor to do further accurate sorting. As a result, excluding the incorrectly identified types of HDPE and LDPE, the final accuracy is given below:

$$Accuracy = \frac{Total_{sorted\_containers}}{Total_{num\_containers} - num_{incorrectly\_HDPE\&LDPE}} = \frac{1668}{2000 - 224} = 93\%$$

Conclusions

The final construction of the design presented in this report is a strong overview of the pillars upon which this recycling facility should be designed around. However, it is not a fully fleshed out plan for the operation of the facility. Looking ahead, specific process units need to be decided upon based on the various factors discussed in this report. Additionally, the size of these units would depend on the actual dimensions of the facility and its storage capabilities which are yet to be determined. Furthermore, the specific logistics that would govern the transportation of the waste to the facility will be pivotal to the stakeholders of the project. This would require substantial cooperation with local authorities as well.

Overall, this project would have benefited substantially from direct consultations with local stakeholders on the matter. Specifically, the socio-cultural and regulatory aspects of the design process were inferred from third party resources and assumptions. The feasibility of some facets of this proposal is also highly dependent on the current state of Hamilton's recycling program and its current operation. Numerous assumptions were also made regarding the current capabilities of the McMaster waste services which would not have been necessary if consultations were held at each point of this report. Addressing this issue would have created a far more in depth report with more accurate justifications for particular design decisions.

A key feature that would have greatly benefited this report would be a thorough environmental assessments at each of the locations considered in this investigation. For example, it was assumed that Lot M would not have been as greatly impacting a location to the environment as the 10 acre field due to its reduced proximity to Cootes paradise and its already developed nature. However, Lot M is also situated to other non protected nature areas that would undoubtedly be affected.

References

ENGINEER 2PX3. (2022). An Advanced Recycling Plant for McMaster University. McMaster University. Retrieved January 31, 2022

Rapoza, K. (2020, Nov 29). *China Doesn't Want The World's Trash Anymore. Including 'Recyclable' Goods.* Retrieved from Forbes: https://www.forbes.com/sites/kenrapoza/2020/11/29/china-doesnt-want-the-worlds-trash-anymore-including-recyclable-goods/?sh=6bacbe857290

Waste Reduction Group Inc. (2019, October). *McMaster University 2019 Solid Non-Hazardous Waste Audit.* Retrieved January 25, 2022, from https://facilities.mcmaster.ca/app/uploads/2020/09/P1012-McMaster-University-2019-Waste-Audit-FINAL.pdf

Wilson, D. C., & Velis, C. A. (2015). Waste management – still a global. *Waste Management & Research*, 1049-1051.

Appendices

Appendix A – Code output

```
Results for running the simulation in testing mode:
Total missed containers = 0
Total sorted containers = 1690
Total mistyped containers = 310

2000 containers are processed in 3985.10 seconds

Process finished with exit code 0
```

Code:

```
import random

from rcplant import *  # using the pip package


def is_PVC(spectrum):  # PVC method is correct
    decision = False
    if 1250 < spectrum.idxmax() < 1275:
        decision = True
    return decision


def is_PS(spectrum):  # PS method is correct
    decision = False
    if 1400 < spectrum.idxmax() < 1500:
        decision = True
    return decision


def is_PP_HPDE_LDPE(spectrum):
    decision = False
    if 2850 < spectrum.idxmax() < 2950:
        decision = True
    return decision


def is_PC_PU_PET_Polyester(spectrum):  # one PC max occurs
```

```
at 1250, others are around 1700 - 1800
    decision = False
    if 1700 < spectrum.idxmax() < 1800 or spectrum.idxmax()
== 1250:
        decision = True
    return decision


def is_PU(spectrum): # PU method succeed
    decision = False
    spectrum_zoomin = spectrum.loc[1575:1500]
    spectrum_zoomin_1 = spectrum.loc[3500:3050]
    if 3300 < spectrum_zoomin_1.idxmax() < 3400:
        if 1500 < spectrum_zoomin.idxmax() < 1575:  #
wavenumber of second max transmittance
            if spectrum_zoomin.max() > 0.010:
                decision = True
    return decision

def is_PC(spectrum):
    decision = False
    spectrum_zoomin_2 = spectrum.loc[1550:1450]
    spectrum_zoomin_3 = spectrum.loc[1275:1250]
    if spectrum_zoomin_2.idxmax() < 1550:
        if spectrum_zoomin_2.max() > 0.09:
            if 0.08 < spectrum_zoomin_3.max() < 0.3: #
based on maximum number condition
                decision = True
    return decision

def is_Polyester(spectrum):
    decision = False

    spectrum_zoomin = spectrum.loc[3000:2750]
    spectrum_zoomin_2 = spectrum.loc[2500:1750]
    spectrum_zoomin_3 = spectrum.loc[3000:2500]
    spectrum_zoomin_4 = spectrum.loc[2000:1500]
    if spectrum_zoomin.idxmax() > 2850:  # wavenumber of
second max transmittance
        if spectrum_zoomin.max() > 0.025:
            if spectrum_zoomin_2.idxmax() < 2000:
                if spectrum_zoomin_3.idxmax() > 2750:
                    if 0.02 <
spectrum_zoomin_4.max() >0.06:
```

```
                        decision = True
    return decision



def is_Pet(spectrum):
    decision = False
    spectrum_zoomin = spectrum.loc[1700:1250]
    if spectrum_zoomin.idxmax() < 1300:  # wavenumber of
second max transmittance
        if spectrum_zoomin.max() > 0.08:
            decision = True
    return decision



def user_sorting_function(sensors_output):
    # This sorting function provides a simple example to
help you understand how to use
    # the variable sensors_output. You need to figure out
more advanced function to achieve
    # a higher sorting accuracy in both 'training' and
'testing' mode

    sensor_id = 1
    spectrum = sensors_output[sensor_id]['spectrum']

    decision = {sensor_id: random.choice(list(Plastic)[0:-
1])}
    if spectrum.iloc[0] == 0:  # For FTIR, if the first
transmittance is 0, it is blank spectra
        decision = {sensor_id: Plastic.Blank}
    else:
        if is_PVC(spectrum):
            decision = {sensor_id: Plastic.PVC}
        elif is_PS(spectrum):
            decision = {sensor_id: Plastic.PS}
        elif is_PP_HPDE_LDPE(spectrum):
            spectrum_zoomin = spectrum.loc[1550:1250]  #
zoom in to check the second max
            if 1350 < spectrum_zoomin.idxmax() < 1450:  #
Difference occurs at the second max transmittance
                decision = {sensor_id: Plastic.PP}
            else:
```

```
                decision = {sensor_id:
random.choice([Plastic.HDPE, Plastic.LDPE])}  # A random
guess
        elif is_PC_PU_PET_Polyester(spectrum):  # This part
need to be updated
            if is_PU(spectrum):
                decision = {sensor_id: Plastic.PU}
            elif is_PC(spectrum):
                decision = {sensor_id: Plastic.PC}
            elif is_Polyester(spectrum):
                decision = {sensor_id: Plastic.Polyester}
            else:
                is_Pet(spectrum)
                decision = {sensor_id: Plastic.PET}

    return decision


def main():
    # simulation parameters
    conveyor_length = 1000  # cm
    conveyor_width = 100  # cm
    conveyor_speed = 5  # cm per second
    num_containers = 2000
    sensing_zone_location_1 = 500  # cm
    sensors_sampling_frequency = 5  # Hz
    simulation_mode = 'training'

    # Add two lists
    identification_lst = []
    actual_lst = []

    sensors = [
        Sensor.create(SpectrumType.FTIR,
sensing_zone_location_1),
    ]

    conveyor = Conveyor.create(conveyor_speed,
conveyor_length, conveyor_width)

    simulator = RPSimulation(
        sorting_function=user_sorting_function,
        num_containers=num_containers,
        sensors=sensors,
```

```
        sampling_frequency=sensors_sampling_frequency,
        conveyor=conveyor,
        mode=simulation_mode
    )

    elapsed_time = simulator.run()  # added last two
arguments
    for item_id, result in
simulator.identification_result.items():
        if result['actual_type'] !=
result['identified_type']:
            print(f"incorrectly identified : {result}")

    print(f'\nResults for running the simulation in
"{simulation_mode}" mode:')
    print(f'Total missed containers =
{simulator.total_missed}')
    print(f'Total sorted containers =
{simulator.total_classified}')
    print(f'Total mistyped containers =
{simulator.total_mistyped}')

    print(f'\n{num_containers} containers are processed in
{elapsed_time:.2f} seconds')


if __name__ == '__main__':
    main()
```

Appendix B – Design Studio Synchronous sheets

Milestone #	Microsoft SharePoint Link (Only McMaster University accounts can access)
Synch DS2	Tut15_Team39_SynchDS2.docx
Synch DS3	Tut15_Team39_SynchDS3.docx
Synch DS4	Tut15_Team39_SynchDS4.docx
Synch DS5	Tut15_Team39_SynchDS5.docx
Synch DS6	Tut15_Team39_SynchDS6.docx
Synch DS7	Tut15_Team39_SynchDS7.docx
Synch DS8	Tut15_Team39_SynchDS8.docx
Synch DS9	Tut15_Team39_SynchDS9.docx
Synch DS10	Tut15_Team39_SynchDS10.docx