Department of Biosystems and Agricultural Engineering
MICHIGAN STATE UNIVERSITY

BE 487 - Spring 2022
Biosystems Design Projects

Ingham County Fairgrounds and Potter Park Zoo Organic Waste Management

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Background

Manure and bedding waste disposal is inefficient and expensive at the Ingham County Fairgrounds in Mason, MI and Potter Park Zoo in Lansing, MI. The fairgrounds pay $6.50/yd^3 for waste disposal with 7,500 yd^3 of manure and bedding produced each year. The waste is sent to a gravel pit where it is turned into mulch. At its current location, the manure and bedding pile at the fairgrounds causes contaminated runoff after each rain, see Figure 1. Unclean runoff can enter water bodies and act as a non-point source pollutant [1].

Figure 1: Fairgrounds waste pile

Potter Park Zoo has a contract with Granger Waste Services to dispose of two 6 yd^3 dumpsters of animal and bedding waste three times a week, going to the local landfill. The disposal costs $582 per pickup. At the Potter Park Zoo, waste is contained in dumpsters which prevents runoff and contamination of the river that floods the backside of their property ever spring, see Figure 2.

Figure 2: Zoo waste dumpsters

Objectives

Design a waste management system that is capable of handling the animal waste stream at the Ingham County Fairground as well as the Potter Park Zoo.

This design should be a cheaper alternative to their current waste disposal methods and if possible, provide the fairground and zoo with some potential revenue.

Finally, the design should have as minimal of an environmental impact as possible. Environmental considerations are of great importance to the county and is a large factor in consideration.

Constraints

Zoo constraints:

- Lies within a floodplain (see Figure 3)
- Feline and primate waste can carry pathogens
- Little available space

Fairgrounds constraints:

- Irregular waste stream
- Possible plastic waste contamination

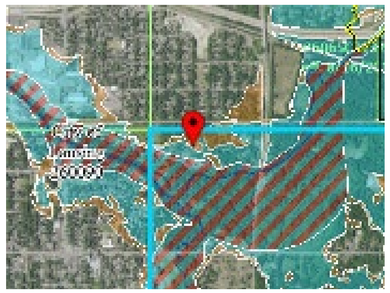

Figure 3: Floodplain (zoo marked in red)

Design Alternatives

To handle the waste flow at both the Ingham County Fairgrounds and Potter Park Zoo, 5 design alternatives were proposed. The proposed options were waste compaction, on-site composting, combined composting, anaerobic digestion, and incineration.

Waste compaction works by pressing waste to decrease its overall volume. The decreased volume of waste, less storage area is required, and less pickups are needed. This option was highly considered for the zoo due to its cost savings, but, outside of reduced emissions from reduced trash pickup, it did not provide significant positive environmental impacts.

Waste composting was considered for both the zoo and fairgrounds independently, along with a solution where both sites' waste would be composted at the fairgrounds. Composting produces a beneficial product that reduces the need for chemical fertilizer, but it also requires significant amounts of space.

Anaerobic digestion produces methane and digestate from waste, which creates a positive environmental impact [3]. Methane can be used as a renewable fuel onsite and decrease heating costs. However, it was the most expensive alternative considered, as it has large capital costs.

Incineration entails burning all waste material to decrease its size. Incineration can release particles harmful to both humans and the environment [4], but it offers large waste management capacity.

Selected Design

All 5 options were evaluated on 7 key design parameters. Each parameter was weighted for its importance in the design, and then all options were evaluated via a decision matrix. The considered parameters are listed below, followed by a parameter description and the weight the parameter held in the decision matrix

- Capacity - ability of the system to handle all produced weight (20%)
- Maintenance requirement - number and length of touches necessary to keep the system operating properly (15%)
- Return on investment - length of time until the system pays for itself (15%)
- Safety - risk occurring to human or animal health from the existence of the system (15%)
- Capital cost - upfront system cost required versus predicted capital budget (10%)
- Environmental impact - harm the system could cause to the environment (10%)
- Space - ability of the system to fit in the provided design locations (10%)
- System independence - necessity of the system to receive outside power or have an outside operator (5%)

The selected design was a combined composting solution for the fairgrounds and and the zoo. The solution consists of a centralized composting site at the Ingham County Fairgrounds and the Potter Park Zoo transporting their waste to the compost site weekly.

This solution was chosen because based on the rating scale it scored 8.4/10 cumulatively, which was not only even with the highest rating of other non-composting alternatives, but the solution was also favored by the clients. Composting is easily scalable which allows adequate design for current organic waste production and later can easily be expanded if necessary. Maintenance requirements do not exceed skills that fairgrounds employees already have. The solution also presents an opportunity for revenue in addition to avoided costs. While it exceeds the budget of the fairgrounds, because it is a combined solution, more monetary opportunities exist within the county and from the zoo.

The composting site design is set up for windrow composting. Two alternative site designs have been proposed by the team. The first design uses the existing tractor, John Deere 5303, with complementing equipment and facility design. The second design uses a new larger tractor, John Deere 6 series, with complementing equipment and facility design. The team recommends the new larger tractor design.

Design Parameters

The elements of this design include site construction planning as well as operational planning. In order to use offsite organic waste and sell a compost product, the compost site must be registered with the Michigan Department of Environment, Great Lakes, and Energy [EGLE]. This requires extensive design plans that manage leachate runoff and consider community impact as well as an operational plan to be submitted for approval.

The composting site will reside in a currently unused field in the southwest corner of the fairgrounds' property. The extent of the field used will be dependent upon the selected design. The design relying on the existing tractor will require approximately three quarters of the field, whereas the design relying on a new larger tractor would only require approximately half of the field.

Figure 4: Compost operational layouts using existing tractor (left) and the new tractor (right). The yellow boxes represent a compost windrow, the blue boxes represent a runoff retention pond.

The operational area will consist of multiple windrows 600-640 ft long to contain the 8,000 yd^3 of the design. This volume exceeds current organic waste production but allows room for growth or additional input from county sources. The design includes a leachate retention pond at 5% of the drainage surface area. These plans must be reviewed by a professional engineer prior to implementation.

In addition to the site planning activities, the team also drafted a compost operations plan [COP] for the fairgrounds. This plan addresses daily operations and weekly deliveries from the zoo. It also addresses safety concerns and details appropriate responses. The the COP details compost management and monitoring with suggested methods. Finally, it addresses final activities such as independent testing, marketing and sales of the compost product.

Economics

Project economics were considered for both project designs to compare the economic advantages and disadvantages. The project budgets contained four key sections, which included subcategories, to capture the full project costs. The four categories were pre-construction costs, construction costs, monitoring costs, and operational expenses. The first three categories provided the capital cost for each project. When using the existing equipment, the expected capital cost was $373,230, and when purchasing new equipment, the expected cost was $395,595.

Yearly operational costs expected for the existing equipment was $30,649, and when purchasing new equipment, the expected cost was $18,318.

Using capitals costs and yearly costs, payback periods were calculated. Payback periods show how quickly a project will pay for itself, which is a significant economic indicator. To calculate the payback period, the yearly cost savings were considered from not having to pay for waste disposal. At the fairgrounds, yearly waste disposal costs are $48,750, which would be an avoided cost with the new compost system. The creation of compost also creates a sellable product, and at average sale prices will create $28,900 in yearly income for the fairgrounds. By comparing the capital costs and yearly operational costs to the avoided costs and income, the payback period was found to be 7.94 years for the existing equipment system and 6.67 years for the new equipment system.

Based on economic value, the new equipment system provides a better payback period than the existing equipment system. While the capital cost is higher, it is recommended that the fairgrounds purchase new equipment to gain the long-term economic advantages as well as having a more capable tractor for other fairgrounds tasks

Select References

1. U.S. Environmental Protection Agency. (2021, July 8). *Basic information about nonpoint source (NPS) pollution*. https://www.epa.gov/nps/basic-information-about-nonpoint-source-nps-pollution.
2. Fronczak, S., & Rogers, E. (2021b, May 11). *Manure management for fairs and exhibitions – hauling, spreading, and composting*. Michigan State University Extension. https://www.canr.msu.edu/resources/manure-management-for-fairs-and-exhibitions-hauling-spreading-and-composting.
3. Chen, L., & Neibling, H. (2014, June). Anaerobic Digestion Basics. University of Idaho Extension. https://www.extension.uidaho.edu/publishing/pdf/CIS/CIS1215.pdf.
4. Extension Foundation. (2019, September 5). *What are the air emissions of burning wood?* https://wood-energy.extension.org/what-are-the-air-emissions-of-burning-wood/.

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