Simulation-Based Optimization for Planning of Effective Waste Reduction, Diversion, and Recycling Programs

PRINCIPAL INVESTIGATOR: Nurcin Celik, Ph.D.
Department of Industrial Engineering,
The University of Miami,
Coral Gables, FL, USA
Telephone: (305) 284-2391
E-mail: celik@miami.edu

TEAM MEMBERS: Eric D. Antmann, Xiaoran Shi, and Yading Dai

WORK ACCOMPLISHED DURING THIS REPORTING PERIOD:
During the first three months of the project, research pertaining to phases I and II of the model was initiated. Concurrent background surveys of discrete event simulation and optimization techniques and the characteristics of large-scale integrated solid waste management systems were carried out. The outcome of these surveys was used to establish a theoretical basis of the proposed framework, and the preparation of the final framework was begun.

Meanwhile, research was also conducted on the Miami-Dade County Department of Solid Waste Management (DSWM)’s integrated solid waste management systems, the largest publicly-owned system of its type in the southeast United States. The team visited DSWM facilities, spent significant time with DSWM staff, and reviewed high-level reports from DSWM and applicable agencies in order to obtain an accurate parameterization of the existing infrastructure. This information will be used to supply data to the framework, establish parameters for the initial case study of the framework, and validate the framework’s output. The following comprise the primary sources used for system parameters:

- 2010 Dade County Department of Solid Waste Management Comprehensive Annual Report
- 2010 Dade County Department of Solid Waste Management Annual Operations Report
- 2011-2012 Metropolitan Dade County Budget

The background survey is approximately 95% complete and the computer framework is approximately 50% complete at present.

INFORMATION DISSEMINATION ACTIVITIES:
TAG Members:
- Dr. Helena Solo-Gabriele, Professor, University of Miami – expertise in environmental impacts of solid waste
- Mrs. Kathleen Woods-Richardson, Director, the Miami-Dade County Department of Solid Waste Management-- expertise in solid waste regulations and operations
- Dr. Jacqueline P. James, Assistant Professor, University of Miami – expertise in landfill design
- Dr. Shihab Asfour, Professor, University of Miami– expertise in planning and optimization of large scale systems
Participants from the Advisory Board and Industry:
- John Schert from Hinkley Center
- Tim Vinson from Hinkley Center
- Ron Beladi from Neel-Schaffer, Inc.
- David Gregory from R. W. Beck, Inc.
- Brenda Clark from H.D.R., Inc.
- Jim Bradner from FDEP and Hinkley Center
- Paul Mauriello from Miami Dade County
- Ram Tewari from Broward County

TAG Meetings:
*The 1st TAG meeting was held on September 23rd, 2011 at the University of Miami.
September 23rd 2011, 9AM
Deans’ Conference Room (Room 289)
McArthur Engineering Building
1251 Memorial Drive, Coral Gables, FL 33146
*We also set up a conference call for those who wanted to attend the meeting remotely.

Scholarly Activity:
*Paper presented at invited poster session at the 2011 Society of Environmental Journalists Annual Conference, in Miami, FL, October 2011

Field Visits:
*The team visited the Miami-Dade County Department of Solid Waste Management’s (DSWM) Resources Recovery Facility on August, 2011. At this meeting, the team presented the objectives and outline of the project, toured the facilities to gain first-hand perspective, and received in-depth information on the operation of the DSWM system.

PRELIMINARY RESULTS:
Solid Waste Management System of Miami-Dade County
In Miami-Dade County’s integrated solid waste management system (DSWM), the solid waste generated by residents and businesses is largely collected via two systems: residential drop-off and curbside or scheduled collection. In the residential drop-off system, residents take hazardous household wastes (i.e. paints, pesticides, fluorescent bulbs, etc.) to one of two Home Chemical Collection Centers, while they must take household trash, yard debris, white goods, and other wastes to one of 13 Trash and Recycling Centers (TRC’s). The waste collected at these centers is
directly transferred to the disposal system for final processing. This research concerns itself with the operations of waste transfer, processing and disposal after it is collected at these centers.

Figure 2: Mass flow diagram for Miami-Dade County’s current solid waste management system.

In the waste stream, some recyclable materials collected must go to the Material Recovery Facility, which is owned by Waste Management, Inc., a private company under contract with the Dade County. Here, the recyclables, including plastic, steel, aluminum, glass, and paper products, are categorized manually and mechanically, packed, and prepared for sale as raw material. The remainder of waste from curbside and scheduled collection is delivered to a transfer station, landfill, or the county’s Resources Recovery Facility (RRF) (a refuse derived fuel waste-to-energy plant). According to DSWM, transfer stations can relieve the pressure that municipal solid waste delivery puts on traffic and save travel time for haulers. From the transfer stations, materials are delivered to either the county’s RRF or one of its two landfills. At the RRF, waste is either lightly processed into a fuel, which is combusted on site to produce electricity, or is converted into a biomass product, which is sold as a low-grade fuel. The ash of combustion is delivered to an onsite monofill facility. At this facility and the county’s other landfills, the best-available technologies, including a sequencing batch reactor to treat leachate and water waste, are employed. Also, a landfill gas-to-energy recovery facility, and a similar landfill gas-to-energy conversion system, will be constructed to reduce emissions and provide energy recovery. Additionally, based on the successful case of the South Dade Landfill, landfill sites can be effectively converted into a natural habitat and wetland for native plants and varied wildlife. Figure 1 provides a detailed mass-flow diagram of the DSMW system.

Proposed Methodology

1. Overview of the Proposed Simulation-Based Decision-Making Framework

In this study, we propose to develop a simulation-based decision optimization framework for solid waste management and recycling planning in Miami-Dade County, FL, with an objective to
achieve the highest recycling rate while balancing both financial and environmental responsibilities. The proposed framework will be comprised of three major components: a database, an assessment module, and a resource allocation optimization module (see Figure 2). The database stores historical data, and filters noise out of the data. As coherent large-scale solid waste management systems are rare (especially in conjunction with waste collection, diversion and recycling operations), obtaining realistic data presented an additional challenge to the proposed modeling approaches. In this study, required historical data are gathered from several credible sources, including the Florida Department of Environmental Protection, the Miami-Dade County Department of Solid Waste Management, Waste Management, Inc., and current studies sponsored by the Hinkley Center. The data is retrieved from this database based on a parameterization, which is conducted by the assessment module. The parameterization is established by the formulation of optimization equations, elaborated in Section 3.3.5. Based on the relationship between the independent variables and dependent variables selected for manipulation at any given time, coefficients are obtained from the assessment module for use as our parameters and starting values, ensuring that the data from the real system and the simulation model are properly connected. In the resource allocation optimization module, parameters selected in the assessment module are used in the optimization equations and constraints to establish the new relationships. Here, we propose to develop a detailed simulation-based model of the solid waste management system in Dade County, Florida, using a combined discrete-continuous simulation modeling approach, and incorporating the parameters identified in the assessment module. The feedback received from the real system is used for the tuning of the proposed model, updating the databases, and enhancing the overall proposed tool for dynamic, data-driven adaptive solutions, as the system evolves and steers the measurement for selective data updates. This way, the proposed tool promises to perform not only for aggregate-level strategic management problems, but also for detail-level operational decisions in the future.

Figure 2: Proposed simulation-based decision making framework for effective solid waste management
2. Assessment Module
In the assessment module, the sources of uncertainty in the existing DSWM system are identified. Generation units (both residential and organizational), recyclable materials, and their associated cost for collection, processing, and transportation are detailed in this section. The major components of the solid waste management and recycling programs are highlighted below. These components are later analyzed quantitatively within the proposed simulation-based optimization model and comprise the basis for the variable set of the optimization mechanism. The large scale of the DSWM and other systems presented significant challenges in developing a concise yet complete parameterization of relevant parameters and uncertainties. The quality of such parameterization is critical for achieving accurate results in the following resource allocation optimization module while keeping computational burden within moderate bounds.

3. Resource Allocation and Optimization Module
The resource allocation optimization module consists of a simulation model incorporating all of the uncertainties identified in the assessment model. The model is built with an aim to represent the life cycle of different types of solid waste in a realistic simulation environment. To this end, the model details the differences in the life cycle processes (i.e., waste diversion, collection, transport, and disposal options) of various types of solid waste (i.e., yard trash, construction and demolition debris, glass etc.) and enables a performance analysis study on possible alternatives. In order to accurately capture the complex, dynamic, and heterogeneous character of SWM systems, the simulation-based optimization features a discrete-continuous simulation with robust capabilities for simulating uncertainties and an embedded optimization mechanism. The high levels of complexity and large scale characteristic of these systems creates significant challenges for the optimization mechanism, due to the size of the possible solution space. The optimization and resource allocation algorithm within this module initiates its operations by generating a candidate solution plan. This algorithm is developed based on meta-heuristics in order to reduce computational burden while enabling the desired accuracy level in the solution. The performance (in terms of cost, percentage of the recycling goal met, and the environmental impact) and effectiveness of this candidate solution plan (or scenario) is evaluated on a quantitative basis using the aforementioned discrete-continuous simulation model, and the procedure repeats itself as the algorithm searches through various candidate allocations. Finally, the same algorithm selects the solution with best performance to be executed and sent to the real system for implementation. The optimization and resource allocation algorithm enforces a multi-criteria approach, considering the conflicting goals of solid waste management involving social (high recycling value and high participation rates), economic (low financial cost), and environmental (low greenhouse gas emissions) objectives.

FUTURE WORK
Work for the following three-month period will focus on model development, verification, and review. All of the components of the proposed computer-based framework will be completed, the case study of the DSWM system will be applied to the system, and experiments will be carried out to validate and refine the proposed framework, and provide practical recommendations to the DSWM system to advance their goals of increasing recycling rates at the minimal possible cost.