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Solid waste management

WASTE MANAGEMENT STRATEGY AT A PUBLIC UNIVERSITY IN SMART CITY CONTEXT

D. E. POPESCU[a], C. BUNGAU[b]*, M. PRADA[c], C. DOMUTA[d], S. BUNGAU[e], D. M. TIT[e]

[a]*Faculty of Electrical Engineering and Information Technology, University of Oradea, Oradea, Romania*
[b]*Faculty of Management and Technological Engineering, University of Oradea, 1 Universitatii Street, Oradea, Romania*
E-mail: *bungau@uoradea.ro*
[c]*Faculty of Civil Engineering, Cadaster and Architecture, University of Oradea, Oradea, Romania*
[d]*Faculty of Environmental Protection, University of Oradea, Oradea, Romania*
[e]*Faculty of Medicine and Pharmacy, University of Oradea, Oradea, Romania*

Abstract. The objective of this study is to analyse the current waste management system in a public university as is the University of Oradea and to develop strategies for improve it. Also, it was made an analysis of how waste was collected, stored and recycled in whole campus, over the period 2010–2015. University of Oradea waste management programs are designed to protect the environment, reduce pollution and encourage recycling throughout community. The present and the future waste management policy of any institution in a city is closely related to that city waste management strategy. After analysing the present situation and addressing the key questions in the Oradea smart city strategy, it has been concluded that the University has to act to prevent generating waste and acting to re-use waste according to the most intelligent collection system of Oradea. With the cost of new technologies steadily decreasing, and plenty of wireless technologies available to make smart waste possible, University of Oradea can significantly improve its waste management system by employing these technologies.

Keywords: waste management program, strategy, smart city.

AIMS AND BACKGROUND

Waste management is represented by all the activities and actions required to manage waste from its inception to its final disposal, and is intended to reduce adverse effects of waste on health, the environment or aesthetics. This includes, collection, transport, treatment and disposal of waste together with monitoring together with regulatory framework that relates to waste management[1–3].

The term usually relates to all kinds of waste, whether generated during the extraction of raw materials, the processing of raw materials into intermediate and

* For correspondence.

final products, the consumption of final products, or other human activities including municipal (residential, institutional, commercial), agricultural, and special (health care, household hazardous wastes, sewage sludge)[2–4].

The European Union approach to waste management is based on the 'waste hierarchy'. The aim of the waste hierarchy is to extract the maximum practical benefits from products and to generate the minimum amount of waste, and it sets the following priority order when shaping waste policy and managing waste at the operational level: prevention, (preparing for) reuse, recycling, recovery and, as the least preferred option, disposal (which includes landfilling and incineration without energy recovery)[5].

The waste hierarchy represents the progression of a product or material through the sequential stages of the pyramid of waste management and the latter parts of the life-cycle for each product[6] (Fig. 1).

The waste hierarchy is represented as a pyramid because the basic premise is to avoid and reduce the generation of waste. The next step is to reduce the generation of waste, i.e. by re-use. The next is recycling, which would include composting. Re-use (without further processing) and recycling (processing waste materials to make the same or different products) keeps materials in the productive economy and benefits the environment by decreasing the need for new materials and waste absorption.

Fig. 1. Waste hierarchy (adapted from Ref. 6)

Where further recycling is not feasible, it may be possible to recover the energy from the material and feed that back into the economy where this is acceptable to the community; so the next step is material recovery and waste-to-energy. Energy can be recovered from processes, i.e. landfill and combustion, at this level of the hierarchy. Some materials may be inappropriate to re-use, recycle or recover for energy and instead require treatment to stabilise them and minimise their environmental or health impacts. The final action is disposal, in landfills or through incineration without energy recovery. The waste hierarchy recognises that some

types of waste, such as hazardous chemicals or asbestos, cannot be safely recycled and direct treatment or disposal is the most appropriate management option. This last step is the final resort for waste which has not been prevented, diverted or recovered[6,7].

Incineration is a disposal method in which solid organic wastes are subjected to combustion so as to convert them into residue and gaseous products. It is used to dispose of solid, liquid and gaseous waste. It is recognised as a practical method of disposing of certain hazardous waste materials (such as biological medical waste). Incineration is a controversial method of waste disposal, due to issues such as emission of gaseous pollutants[8].

Waste management practices are not uniform among countries (developed and developing nations), regions (urban and rural area), and sectors (residential and industrial)[9].

In line with this the 7th Environment Action Program sets the following priority objectives for waste policy in the EU (Ref. 10): to reduce the amount of waste generated; to maximise recycling and re-use; to limit incineration to non-recyclable materials; to phase out landfilling to non-recyclable and non-recoverable waste and to ensure full implementation of the waste policy targets in all Member States.

The objective of this study is to analyse the current waste management system within University of Oradea and to develop strategies to improve it.

EXPERIMENTAL

We did an analysis of how the waste were collected, stored and recycled at the University of Oradea during the period of 2010–2015.

We also determined the total amount of waste produced each year and the amount of each type of selective waste collection detailing the different types of waste. Following the analysis we identified opportunities in developing solutions that lead to integration of the university waste management with the smart city concept, which is envisaged for implementation by the city of Oradea.

RESULTS AND DISCUSSION

University of Oradea waste management programs are designed to protect the environment, to reduce the pollution and, probably just as importantly, to keep refuse rates low. We encourage recycling throughout the academic community. The university goal is to have 100% of the residents of our university as active participants in the recycling program.

University of Oradea provides 4 stream recycling cart to each household to recycle. The recyclable items can go inside the appropriate cart. The policy of university includes to have separate cart for: glass, paper, plastic pats and domestic waste. These are also collected separate. The university vision is to promote

positive behaviour change and lead to improvement in the environment and community wellbeing.

From the university point of view that a good environmental practice means to:

– plan how to apply the waste hierarchy;

– monitor the performance regularly;

– know what type of waste is produced and make efforts to reduced it;

– sort and segregate the waste produced to help the recovery process.

The amount of waste collected in time from our university is presented in Table 1.

Table 1.Types of selectively collected waste in 2010–2015

Type of waste	Unit of measure per year	Year					
		2010	2011	2012	2013	2014	2015
Selective waste eco Bihor (plastic)	m^3	200	200	280	240	300	290
Glass		0	5	3	10	15	17
Textile		0	60	296	300	320	300
Wood		35	60	25	35	50	50
Total		235	325	604	585	685	657
Electrical	t	1.6	5.42	6.4	6.5	7	6.8
Paper		1.22	2	1.04	2	2.5	2.5
Tires and inner bags		0	0	1.5	0.9	1	1.1
Household		700.9	673.38	835	661.16	453	490
Metallic		13.232	16.467	33.051	13	15	15
Total		716.952	697.267	876.991	683.56	478.5	515.4

There is a progressive increase in the quantity of waste textile and glass, respectively fluctuations in increasing and decreasing of wood type waste in the last six years because, during this period, numerous investments in construction and renovations were made.

For most materials, the waste hierarchy ranking applies as is described in Fig. 1. Some current research identified some materials, for which the waste management options which are not in keeping with the waste hierarchy order are better for the environment[11]:

– for food, the anaerobic digestion is environmentally better than composting and other recovery options;

– for garden waste and for mixtures of food waste, dry anaerobic composting digestion followed by composting is environmentally better than composting alone;

– for wood lower grade wood energy recovery options are more suitable than recycling.

It is important to identify the activities required for managing the waste that allow to establish the activities that must be done at our university in order to optimise the entire waste management process and to find the best solution for integrating this university as part of Oradea future smart city (Table 2).

Table 2. Activities for managing different types of waste (adapted from Ref. 11)

Types of waste	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Paper and card	X	X				X				X					X
Food	X							X	X						X
Garden waste	X							X[*8]	X						X
Textiles	X	X				X				X					X
Wood	X	X				X				X[*5]					X
Glass	X	X				X[*2]				X					X
Metals	X	X				X							X		X
Plastics±	X	X			X	X[*4]				X					X
WEEE [*1]	X	X				X[*3]				X[*6]					X
Tyres	X		X	X			X			X[*7]	X	X		X	X

1 – prevention; 2 – preparation for re-use; 3 – re-treading. 4 – recovery: use in road surfaces; 5 – close loop recycling; 6 – recycling; 7 – re-treading; 8 – anaerobic digestion; 9 – composting: other energy recovery technologies; 10 – energy recovery; 11 – other recovery; 12 – gasification /incineration with EfW; 13 – recycling after energy recover; 14 – microwave treatment; 15 – disposal; [*1] WEEE – Waste Electrical and Electronic Equipment; [*2] other; [*3] plastic & metals; [*4] other; [*5] or lower grade materials; [*6] suitable for non-hazardous mixed plastic; [*7] in cement kilns & through pyrolysis; [*8] dry.

In Table 1 we gave the waste quantities produced by our university. In order to put in practice the hierarchy from Fig. 1, we have first to find the answers at the following problems:

1. Is this university dealing with waste in the best environmental way?

2. Can the university send more waste to a business which can act for re-using it (exclude hazardous waste)?

3. Can the university recycle more waste materials by sorting it better? The way the waste is segregate has an impact on the ranking of available waste management options.

4. Can any food or garden waste be handled by the university to be used for AD? Or can it be composed (if the answer is no).

ORADEA – A FUTURE SMART CITY

The present and the future waste management policy of any institution is closely related to the city waste management strategy.

So, it is important to point out that Oradea wants to connect all the public institutions to a single online platform and to become the first ‘smart city’ in the

country. The first step will be to create the platform. Then, each institution in the city have to connect to it. Fees and amenities will be found on this structure simplifying the work of officials and people will be easier. On the other hand, Oradea residents should no longer have to go from one institution to another (no matter if it is a school, a hospital, a public transport company, and so on) as they will be able to make several operations online, from tax payments to medical appointments.

A new perspective for implementing smart cities is offered by *The Internet of Things* (IoT) – specifically low power, wide-area networks (LPWANs). The IoT is taking a previously splintered system and is combining it seamlessly. Now, cities can gain key insights into disparate agencies, and data can be shared across the city IoT network[12]. Internet of Things (IoT), in a smart city context, can be used to improve citywide services like trash, parking, streetlights, police call buttons, water meters and leak detectors, and more. These wireless sensor and control networks need to run on batteries, but only require the transfer of small amounts of data.

Our waste management solution. After analysing the present situation and answering to the above 4 questions, we conclude that we have to act in the following directions:

– Preventing the waste. The University intends to increase the use of education regarding the general problem of Waste Less, and Recycle More in all the universities programs, so that we attend to increase the implication of the entire university community in this domain. Other studies[13–16] have demonstrated the strong positive impact of education on the environmental protection and pollution reduction at the population level.

– Acting for re-using the waste – according to the most intelligent collection system of Oradea (SIGUREC), which offers a good trade-off to its customers. In present there is a station located in the parking lot of Carrefour (Fig. 2) (Ref. 17).

Classifying the waste. We intend to classify the university waste according with the categories admitted by these systems, which have the most advanced electronic system that allows the identification of the type of waste and its weight. SIGUREC can receive over 10 types of recyclable waste: PET bottles, aluminum cans, glass, electrical equipment, batteries, lamps of other lighting equipment, paper, cardboard, polystyrene as well as other types of plastic packaging. And the best thing is, collectors are rewarded for their effort. This new system helps to raise the level of collection and recycling of waste; in present it is complementary to the existing waste collection infrastructure, it adds a new layer of collection, one with IT functionality. It is important to mention that in 2013, in Oradea, more than two thousand t of waste were recycled and over 40 thousand t of waste were collected from the streets[18].

Fig. 2. Geological location in Romania/Oradea of SIGUREC system

The system offers for the recyclable waste brought, an instant bonus: a shopping or charity voucher whose value varies based on the type and volume of waste.

Our strategy is to make steps for the installation of such a system in the University campus.

Smart waste management. It includes two innovative functions which are very important for waste management service providers of all types[13].

The first one is related with the increasing of the *operational efficiency*, which means to reduce the amount of time and energy required to provide waste management services.

Public services and waste management companies have seen only limited innovation with operational efficiency – until the last few years. One big problem that they have faced is that it is better to pick up trash receptacles too often than being too full.

They could only improve route efficiencies, while still meeting the needs of their customers. But, the sanitation specialists must still physically go to the dumpster to check trash levels. Because of this, trucks often visit containers that do not need emptying, which wastes both time and fuel. The jump was performed with the Internet of Things (IoT). So, smart sensors and sensor-level M2M technology have begun to be used even for displaying trash receptacles.

A great example of an innovative waste company is Enovo[17]. They have created a proprietary dumpster sensor and software system that, when placed on the lids of garbage receptacles, can communicate to the waste management company whether the container is at full capacity, when it needs to be emptied, what tem-

perature the container is at, and more. It allows the sanitation specialists to work more efficiently and cut unnecessary costs. The sensors can also help the company to forecast when a dumpster will be full, allowing them to plan ahead future routes. These increased efficiencies can cut costs by up to 50% (Ref. 17).

The architecture of our proposed solution is given in Fig. 3.

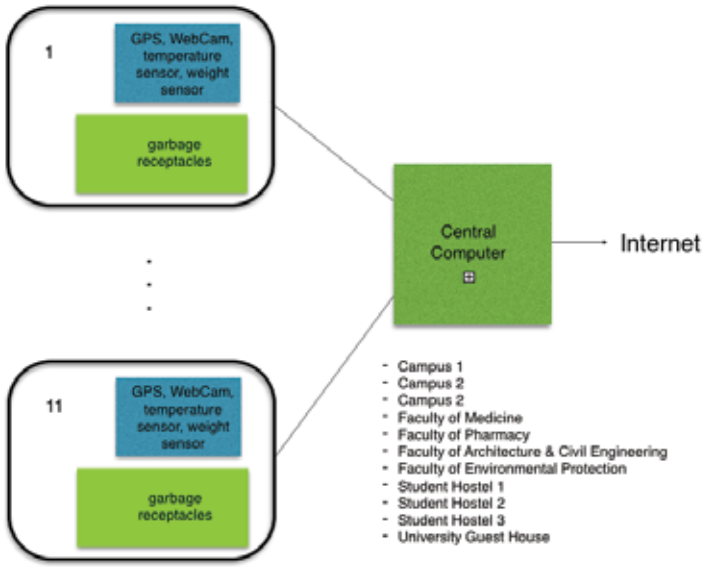

Fig. 3. Architecture of our proposed solution

We intend to use a garbage receptacle for each geographical location of our university, equipped with a Webcam, a temperature sensor and a weight sensor, controlled by a local microcontroller, which will be used to communicate via Intranet to a Central Computer the information regarding the container state. This Central Computer will have a friendly interface for monitoring the entire university waste state and it will be used for notifying by Internet the waste management company whether the container is at full capacity and it needs to be emptied. It will communicate also what temperature the container is at, and even an image with the container.

The second innovative function, important for the smart waste management is to *reduce the amount of waste created*, it deals with managing the big quantity of waste created on a daily basis. This could be dramatically reduced with the right M2M applications in place, which could help with things like asset and material tracking[18–20].

For example, using the appropriate IoT technology, every store could track exact quantities of specific products they regularly sell, cut back on waste, and reduce defacement[20].

Another example refers to the smart refrigerators that may be able to bring the IoT technology into the home, allowing people to consume their purchases in their terms of validity, becoming more attentive to their foods[20].

Both private waste management services and municipalities can benefit from smart waste technology. For a small upfront cost in a sensor technology, the operational efficiency can be increased and costs can be cut in multiple areas.

Moreover, the proposed solution brings a major advantage for waste collection companies because they can optimise the cost of transport by establishing daily collection routes for cars, depending on the needs transmitted over the Internet by customers.

CONCLUSIONS

Environmental protection and waste management are two notions that complement and complete each other. It is vital for us to understand the nature of our actions and most importantly the consequences derived from our actions. It is very popular nowadays to talk about recycling, and we can even say it is trendy to be an environmentalist. But behind fashion trends and beyond a certain need for compliance due to rules and regulation or have to be aware of the fact that this matter of the waste is one that concerns us all. Our endeavor has focused on the high variety of waste collected in a university campus and what are the best solutions for improving the waste management in the context of a smart city, for which we proposed a practical solution with the architecture described in Fig. 3.

With the cost of these technologies steadily decreasing and plenty of wireless technologies available to make smart waste possible – University of Oradea can stop throwing cash and efficiency in the trash and make a solid business case for this type of investment.

Further, a future research must to evaluate whether the propose solution will be implemented on premise or in cloud-based environment[21]. On the other hand, the Central Computer can be used as a device which can be connected to a Cloud Service Management System[22] that provides IT services for different companies from Oradea, interconnected in an innovative cluster for smart waste management services.

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