An Introduction to Sustainability Considerations in Integrated Waste Management; an Eco-Efficiency Approach

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ABSTRACT

Integrated Waste Management (IWM) is a tool for proper management of solid waste. It is a comprehensive plan specifying the quantity and composition of generated waste, details of services required to store, collect, transport and dispose the waste, separation manner of recyclable and non-recyclable materials at origin, waste minimization and pollution control procedures, hazardous waste management instructions as well as all possible strategies for minimization of waste generation. In other words, Integrated Waste Management is seeking to establish an eco-efficient management system by which the least possible economic cost and social consequences are imposed to the civil society while ensuring the sustainability of natural systems. The present study is an introduction to the role of eco-efficiency approach in Integrated Waste Management. The paper content will explain how an eco-efficiency approach could be assessed in waste management system.

INTRODUCTION

Integrated Waste Management (IWM) is an eco-friendly approach avoids contamination of the environment through sanitary disposal of generated wastes. In addition, it promotes public health and living conditions of local communities. Extracting green energies and recycling, IWM fascinates economic use of natural resources and sustainable development. Over the past decades, the waste management in European countries has been converted into a complex system consisting of various waste treatment and disposal processes as a distinctive feature of "innovation and high-tech applications". Concurrent with the formation of complex waste management systems in European countries, IWM has become a major issue in Asian countries by the rapid economic growth. In order to assess the contribution of a waste management system on sustainable development, it is necessary to consider all the factors affecting the complexity of the system. These factors are classified into three main groups of legal framework conditions, local framework conditions and socioeconomic conditions (Figure 1).

Waste management systems which include collection, transport, and disposal stages can be assessed by efficacy indices. The indices can provide the opportunity to assess current environmental and economic conditions of waste management in cities. Moreover, the changes in management strategies including waste recycling, composting, energy extraction and landfill will be evaluated by sustainability assessment to determine the efficiency the systems. Based on Wursthorn et al. [22], eco-efficiency links economic efficiency with environmental efficiency with the purpose of identification and implementation of activities to enable production that is both economically more efficient and cleaner so that parameters with a high indicative value have to be used. According to the definition of the World Business Council for Sustainable Development (WBCSD) in 1991, eco-efficiency is "the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resources intensity throughout the life cycle, to a level at least in line with the Earth's estimated carrying capacity" [22]. Nowadays, eco-efficiency has been the center of attention in various fields of biodiversity [11], companies [4], iron rod industry [6], petroleum and petrochemical plants [2], household electric and electronic products [7] and lots of others. The concept of eco-efficiency is somehow a novel approach in waste management so that there are relevant studies focusing on measuring and improving the economic and ecological efficiency of waste management worldwide. Kielenniva et al. [8] measured eco-efficiency of contaminated soil management at the...
They used Life Cycle Analysis (LCA) and Material Flow Analysis (MFA) to identify factors that the environmental indicators should cover, and also involved economic indicators. They finally introduced a total of 28 indicators classified into three different categories: background indicators, environmental indicators and economic indicators. Zhao et al. [23] investigated the eco-efficiency of greenhouse gas emissions mitigation of municipal solid waste management in Tianjin, China. They found that there is no linear relationship between the global warming impact and the cost impact in MSW management system in Tianjin. The use of directional distance functions and Data Envelopment Analysis (DEA) was proposed Picazo-Tadeo et al. in 2012 assessed the eco-efficiency of olive-growing in Southern Spain. Winter et al. [21] determined the parameters of optimal process to increase the eco-efficiency of grinding processes. Lukas and Welling in 2014 analyzed timing and eco-efficiency of climate-friendly investments in supply chains. In 2014, Song estimated both the in-port ship emissions inventory (CO₂, CH₄, N₂O, PM₁₀, PM₂.₅, NOₓ, SOₓ, CO, and HC) and the emission associated social cost in Yangshan port of Shanghai. Park and Kumar Behera in 2013 proposed eco-efficiency indicator as an integral parameter for simultaneously quantifying the economic and environmental performance of industrial symbiosis (IS) networks.

![Fig. 1: factors affecting IWM][3]

**The history of eco-efficiency:**

Eco-efficiency was first described by Schaltegger and Sturm in 1989 and then formally issued in 1992 in the book Changing Course by Stephan Schmidheiny with the WBCSD and at the 1992 Earth Summit, eco-efficiency was endorsed as a new business concept and means for companies to implement Agenda 21 in the private sector [15]. Since after it was applied and developed in an extensive manner. Today a growing number of companies, organizations, governments, consultants, and academics are using and interpreting eco-efficiency for their own projects and benefit. Nowadays, the number of companies, organizations, governments, consultants, and academics enjoying the advantages of eco-efficiency for their own projects and benefit is ever increasing.

**Main aspects of eco-efficiency:**

WBCSD in 2003 listed the critical aspects of eco-efficiency as follows [9]:

1. Legal framework
   - Includes regulations related to:
     - Waste collection, transfer and disposal
     - Reduced amount of emissions
     - Energy consumption
     - Water resource protection, etc.
2. Local conditions
   - Such as population, area, infrastructures, etc.
3. Socioeconomic aspects
   - Cost, income
   - Tax, Finance, Credit
   - Job creation
4. Waste management system
   - Waste characteristics
   - Process parameters
5. Waste Management System Modeling
6. Assessment of waste management systems efficiency assessment

The history of eco-efficiency:
A reduction in the material intensity of goods or services;
- A reduction in the energy intensity of goods or services;
- Reduced dispersion of toxic materials;
- Improved recyclability;
- Maximum use of renewable resources;
- Greater durability of products;
- Increased service intensity of goods and services.

Considering the main aspects of the eco-efficiency a variety of indicators have yet been developed to make it possible to trace quantitatively the economic and ecological performance of industries and decision makings.

**Key characteristics of Eco-efficiency:**

The declined ecological impacts refer to an increase in resource productivity resulting in a competitive advantage. All versions of eco-efficiency share four key following characteristics:

- Confidence in technological innovation as the main solution to un-sustainability;
- Reliance on business as the principal actor of transformation. The emphasis is on firms designing new products, shifting to new production processes, and investing in R&D, etc., more than on the retailer or the consumer, let alone the citizen.
- Trust in markets (if they are functioning well);
- "Growthphilia": there is nothing wrong with growth as such [1].

**Integrated Waste Management:**

Solid waste management (SWM) has been an issue of increasing global concern as a result of continuous urban population rise and increasing consumption patterns. The health and environmental implications associated with SWM are of great importance, particularly in the context of developing countries [12]. Waste generation increases with population expansion and economic development and improper management of solid waste causes environmental and health risks including contaminating water, attracting insects and rodents, safety hazards from fires or explosions, increased greenhouse gas (GHG) emissions resulting climate change [20,14,13]. Amongst factors complicating SWM in developing countries can be pointed to urbanization, inequality, and economic growth; cultural and socio-economic aspects; policy, governance, and institutional issues; and international influences [12]. These obviously reveal the determining role of integrated approaches involving all the affective factors in IWM. In other words, there is a need for re-evaluation of the resource, society and environment scenarios with a view to the totality of the system and with proper analysis of the flow of water and matter through society [5]. According to USEPA [20] Integrated Solid Waste Management (ISWM) is a comprehensive waste prevention, recycling, composting, and disposal program (Figure 2), each of which requires careful planning and financing.

![Fig. 2: Integrated Solid Waste Management [20]](image)

**Eco-efficiency of IWM:**

Like any other management systems, IWM must be efficient both economically and ecologically. Finding appropriate ways to raise the efficiency of IWM systems and presenting indicators to measure their efficiency are of main duties of waste management authorities. Scientists now believe that, by proper use of resources, recycling and reuse of waste, energy recovery from generated wastes, and minimization of emissions caused by waste disposal; waste management systems in the world would be much more efficient than ever before. Table 1 demonstrates some of useful criteria could be applied to assess the eco-efficiency of WMS.
Table 1: A number of criteria to evaluate the eco-efficiency of WMS

<table>
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<th>Indicator</th>
<th>Indices</th>
<th>Overall Status</th>
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| Area covered by the Waste Management          | - total area
- number of cities and villages covered by the management system
- Number of neighborhoods
- total population
- total households
- Types of industrial activities in the area
- State of the road network                      | - Satisficing
- Not so good
- undesired                                      |
| Waste quantity                                | - total annual tonnage of waste
- total annual tonnage of municipal waste
- total annual tonnage of industrial waste
- total annual tonnage of hazardous waste
- daily generation rate of waste per capita (kg / capita / day) | - accurate estimation
- approximate estimation
- poor estimation                                 |
| Waste composition                             | - providing a list containing full details of generated waste
- Full details of waste by type of waste Manufacturers
- Full details of recyclable components
- Full details of hazardous components           | - completed
- in progress
- never                                          |
| Waste separation                              | - separation at origin in order to isolate biodegradable components
- separation at origin in order to isolate green wastes
- separation at origin in order to isolate inorganic wastes
- separation of organic wastes in recycling centers
- separation of inorganic wastes in recycling centers
- separation of toxic or hazardous wastes         | - completed
- in progress
- never                                          |
| Waste collection                              | - collection of dumped waste from house to house
- collection of mixed waste from house to house
- collection of mixed waste from arbitrary delivery points
- Initial collection of separated waste* and transfer to the delivery points
- Initial, elective collection and transfer to the disposal points
- separate collection of waste separated at origin
- access to appropriate waste collection fleet
- low capacity of available waste collection fleet compared to the current needs
- investments in modernization of the fleet       | - completely
- partially
- never                                          |
| Recycling                                     | - composting
- anaerobic digestion (methane generation)
- cardboard and paper recycling
- plastic recycling
- Ferrous and metal waste recycling
- non-ferrous and non-metal waste recycling
- Glass recycling
- recycling certain types of special or hazardous wastes | - Yes
- Partially
- No                                               |
| Final disposal                                 | - unsafe officially open dump sites
- aerobic burning of waste at both formal and informal open dumping sites | - never
- partially
- always                                        |

Conclusion:
In general conclusion, there is a verity of criteria make a waste management system efficient ecologically and economically. As a dirty gold, waste will be an economic source with the lowest possible environmental impact if high efficiency strategies are adopted at all stages of waste generation to disposal. Accordingly, separation at origin, recycling and energy extraction could be three main, effective approaches significantly improve the eco-efficiency of WMSs.

REFERENCES