

Evolving the Theory of Waste Management – Implications to waste minimization

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Abstract

The Theory of Waste Management is a unified body of knowledge about waste and waste management, and it is founded on the expectation that waste management is to prevent waste to cause harm to human health and the environment and promote resource use optimization. Waste Management Theory is to be constructed under the paradigm of Industrial Ecology as Industrial Ecology is equally adaptable to incorporate waste minimization and/or resource use optimization goals and values.

Keywords: Industrial Ecology, waste, waste minimization, waste management, theory

Introduction

The 20th century witnessed an unprecedented rate of technological development. Technological development is where scientific research meets engineering design. Consider the development of information technology. Within the lifetime of an adult human, electronic devices have evolved from luxury items accessible to only a select few, into millions of tonnes' worth piles of junk, puzzling entire nations, alerting legislators and environmental authorities. It appears so that technology has been selective in adopting scientific advances, and disregarded the heeds of environmental science: products and technologies were developed, time and again, with no considerations for recovering and re-circulating material resources. The electronic waste problem of the present is caused by the fact that electronic equipment now entering the waste stream have not been designed with disassembly, re-use or recycling in mind. With our present knowledge of causalities, the WEEE legislation was introduced in an attempt to stop this avalanche of fine metals and plastics assembled in ingenious ways. However, legislation only sets the goal, but does not pave the road to it. There appears to be a gap between science and technology, one that can be bridged by technical theories.

Constructing the Theory of Waste Management

Waste Management Theory (WMT) has been introduced to channel environmental sciences into engineering design. WMT is a unified body of knowledge about waste and waste management. It is an effort to organise the diverse variables of the waste management system as it stands today. WMT is considered within the paradigm of Industrial Ecology, and built side-by-side with other relevant theories, most notably Design Theory. Design Theory is a relatively new discipline, still under development. Following its development offers valuable insights about evolving technical theories. According to Love (2002), it is crucial to theory development to integrate theories from other bodies of knowledge, as well as the clarification of the definitions

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of core concepts, and mapping out key issues, such as domains, epistemologies and ontologies. At the present stage of WMT development, scientific definitions of key concepts have been offered, and evolving of WMT under the paradigm of Industrial Ecology is in progress.

The function of science is to build up systems of explanatory techniques; a variety of representative devices, including models, diagrams and theories (Toulmin 1953). Theories can be considered milestones of scientific development. Theories are usually introduced when previous study of a class of phenomena has revealed a system of uniformities. The purpose of theory is then to explain systems of regularities that cannot be explained with scientific laws (Hempel 1966). Formally, a scientific theory may be considered as a set of sentences expressed in terms of a specific vocabulary. Theory will always be thought of as formulated within a linguistic framework of a clear specified logical structure, which determines, in particular, the rules of deductive inference. (Hempel, 1965)

Take the example of the definition of waste. The European Commission and Member States were gathered for a two-day workshop in Leipzig on February 25-26 2004, to discuss the classification of treatment operations and of the waste definition. One of the observations of the Leipzig workshop was that “using the definition of waste is a tricky affair when determining when something becomes waste and when it stops being waste.” To the first situation belongs among others the placing of re-use, the application of the definition of waste to end-of- life vehicles. To the second belong for example treated construction and demolition waste (ISWA 2004). The basic proposal of WMT is that it is able to define waste unambiguously. Four waste classes have been defined (Table 1).

Table 1 Classes of waste (Pongrácz and Pohjola 1997).

Class 1	Non-wanted things, created not intended, or not avoided, with no purpose.
Class 2	Things that were given a finite purpose, thus destined to become useless after fulfilling it.
Class 3	Things with well-defined purpose, but their performance ceased being acceptable due to a flaw in their Structure or State.
Class 4	Things with well-defined purpose, and acceptable performance, but their users failed to use them for their intended purpose.

The taxonomy of waste in Table 1 was formulated using an object oriented modelling language, PSSP™, which is based on the ontological commitment that every real thing can be formalised as an object having four attributes: Purpose, Structure, State, and Performance (Pohjola and Tanskanen 1998).

Using the taxonomy of Table 2, all of the problem waste definition areas defined in the Leipzig workshop were possible to identify as follows (Pongrácz et al. 2004):

- Re-use happens when a thing that has just performed its purpose and momentarily no new purpose is assigned to it. This generally applies to wastes of class 2. A thing that has fulfilled its purpose is not necessarily useless. It is because usefulness is defined by structure and state, while re-use is subject of purpose. As long as structure and state allow performance with respect to the assigned purpose, re-usable things shall not be considered wastes. An empty bottle, whose Structure is undamaged is thus a useful non-waste.
- End-of-life vehicles represent wastes of class 3. They are aggregate things composed of numerous structural parts. The loss of performance can be attributable to the inability of one or several structural parts to perform their purpose. Repair or changing the faulty structural parts can extend useful life.

In case the of owner abandonment despite of acceptable performance, the car represents waste class 4. Unless the owner argues that the car did not meet his expectations of superior performance usually attributable to newer cars. On the positive side, finding a new owner willing to tolerate the shortcomings of a new car would render it non-waste.

- Demolition waste can be viewed as waste of class 2, one that has fulfilled its purpose. When a structurally intact tile is separated from the aggregate object of demolition waste, it can be assigned a new purpose and thus it shall no longer be considered waste.

Table 2 Waste minimization measures vs. Industrial Ecology principles (Pongrácz).

Waste minimization measures	Industrial Ecology principles
Strict avoidance of waste creation/ prevention at source	Every molecule that enters a specific manufacturing process should leave that process as part of a saleable product.
	Every erg of energy used in manufacture should produce a desired material transformation.
Reduction of waste by application of more efficient production technologies	Industries should make minimum use of materials and energy in products, processes and in services
Source-oriented improvement of waste quality, e.g. substitution of hazardous substances;	Industries should choose abundant, non-toxic materials when designing products.
Re-use of products or parts of products	Every process and product should be designed to preserve the embedded utility of the materials used. An efficient way to accomplish this goal is by designing modular equipment and by remanufacturing
Disassembling of complex products and re-use of components	
Internal recycling of production waste	Industries should get most of the needed materials through recycling streams (theirs or those of others) rather than through raw materials extraction, even in the case of common materials
External recycling	Every product should be designed so that it can be used to create other useful products at the end of its life.
	Every industrial landholding or facility should be developed, constructed or modified with attention to maintaining or improving local habitats and species diversity, and to minimising impacts on local and regional resources.
	Close interactions should be developed with materials suppliers, customers, and representatives of other industries, with the aim of developing co-operative ways of minimising packaging and of recycling and reusing materials

Waste minimization – resources use optimization

Prevention of waste creation is the main priority of waste management, which corresponds to the principal goal of waste management: conservation of resources. Moving toward waste minimisation requires that the firm commits itself to increasing the proportion of non-waste leaving the process. It has been agued that, it follows from the laws of thermodynamics, that

producing by-products is concomitant of a main product (Baumgärtner & de Swaan Arons 2003). For this reason, industrial firms have to look beyond their factory walls, and seek for external utilization of their waste, in accordance with the principles of Industrial Ecology (IE). If we accept that waste minimization and resources use optimization is the most important objective of waste management (Pongrácz 2002), it is essential that WMT is to be considered together with IE, as resource use optimization considerations reach beyond the tradition scope of waste management. It was argued that there is considerable overlapping between the goals of IE and waste management where waste minimization is concerned. In Table 2, the principles of IE (Graedel and Allenby 1995), and waste minimization measures (Vancini 2000) are listed.

From Table 2 one can clearly recognize goals and principles similar in IE as well as waste minimization. The main difference comes from the larger scale of IE: it reaches far beyond the walls of an industrial facility, and encourages responsible co-existence with the surrounding environment and creating interlocking eco-systems with other companies to achieve an efficient circulation of materials. It is, however, important that industrial facilities learn to internalize global objectives into their local solutions, and it is here where WMT can assist. (Pongrácz.)

Industrial Ecology and Waste Management

WMT is constructed under the canopy of IE (Figure 2). IE, as applied in manufacturing, involves the design of industrial processes and products from the dual perspectives of product competitiveness and environmental interactions. A systems-oriented vision, built on the principle that industrial design and manufacturing processes are to be considered in partnership with the environment (Graedel & Allenby 1995), is what sustainable waste management needs to grow into. Embracing the principles of IE, WMT will be instrumental in optimizing resources use.

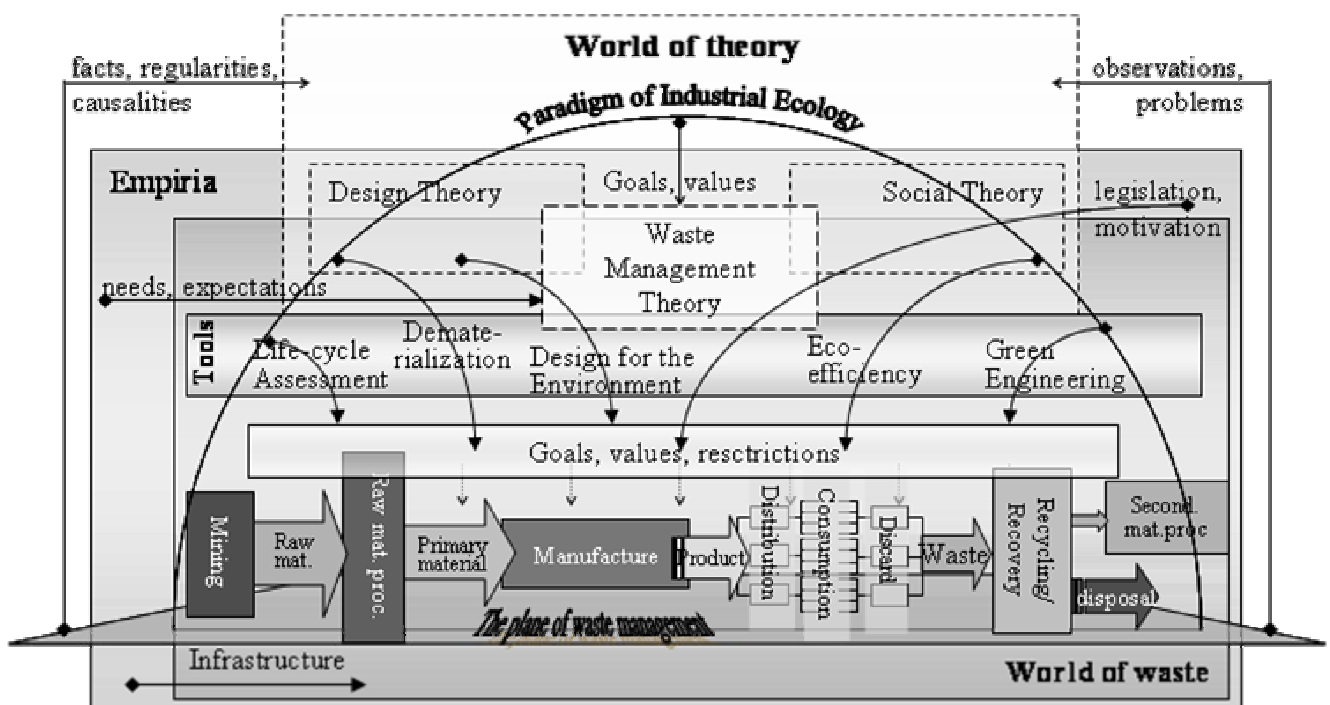


Fig. 2 Waste management under the domain of Industrial Ecology (Pongrácz).

Figure 2 illustrates how WMT is positioned between other relating theories, and what tools need to be used to achieve the objectives of IE. The ‘world of waste’ is emphasised from “Empiria,”

to highlight the influencing factors on designing waste management. It draws data from the existing waste management infrastructure, and is restricted by its legislative constraints. On the plane of waste management," WMT seeks to optimise resources use from virgin raw material, to discard. The goals, values for resources optimization originate from the paradigm of Industrial Ecology. It was argued that the goals in IE have to be adapted by WMT and to translate the goals of IE so that they are applicable to an industrial unit (Pongrácz). The majority of tools that are to be adapted to industrial waste management originate in IE, however, some tools are also influenced by Design Theory. Social aspects are also taken into account, principles such as sufficiency, morals and responsibilities will have to be introduced into the goals and values to be followed. From the "real world" surrounding the waste management domain, human needs and expectations also affect the objectives set out by WMT. Finally, theory is continuously developed and updated based on facts, regularities and observations as well as the process of explaining observation and answering domain specific queries.

Conclusions

To be able to design and adopt the most appropriate waste management system, a proper theoretical background has to be established. It can be asserted that when one is looking for a scientific systematization, and ultimately aiming at establishing an explanatory and predictive order among the domain problems of waste management, a theory is required. It was argued that Waste Management Theory is to be built under the paradigm of Industrial Ecology, and their side-by-side advancement can greatly contribute to the development of a sustainable agenda of waste management. The Theory of Waste Management is based on the considerations that waste management is to prevent waste causing harm to human health and the environment, and application of waste management leads to conservation of resources. However, Industrial Ecology successfully combines waste minimization and resources use optimization measures, and ensures that resources are effectively circulated within ecosystems.

Research continues to evolve the Theory of Waste Management, which will assist in incorporating environmental concerns into industrial process and product design.

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